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LABORATORY EVALUATION OF MULTIVISCOSITY-GRADE ENGINE OILS IN U.S. ARMY DIESEL ENGINES

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By

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Under Contract to

**U.S. Army Mobility Equipment Research
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Seven multigrade engine oils were tested against 10 grade and 30 grade reference oil in the DD 6V-53T engine using a 240-hour tracked-vehicle cy- clic endurance test and in the Teledyne Continental LD/LDT-465 engines using a 210-hour wheeled-vehicle cyclic endurance test. The results of these tests are tabulated and compared with results from reference oil tests. Two SAE 15W-40 oils proved equal or better than the reference oil and were recommended for adoption as MIL-L-2104 oils. Recommendations for (contd)		

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further research are also presented.

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FOREWORD

The work reported herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory (USAFRLRL) located at Southwest Research Institute, San Antonio, Texas, under Contracts DAAK70-78-C-0001 and DAAK70-80-C-0001, during the period November 1978 through June 1980. The contracting officer's representative was Mr. F.W. Schaekel of U.S. Army Mobility Equipment Research and Development Command (USAMERADCOM), DRDME-GL, Ft. Belvoir, Virginia, and Mr. Tom Bower of the same office was the technical project monitor.

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TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION.....	5
II. OBJECTIVE AND SCOPE.....	6
III. EXPERIMENTAL PROCEDURES.....	6
A. Test Lubricants.....	6
B. Test Engines.....	7
C. Test Cycles.....	13
D. Test Procedures.....	14
1. 6V-53T Engine.....	14
2. LD-465-1 and LDT-465-1C Engines.....	16
E. Test Evaluation.....	18
IV. DISCUSSION OF RESULTS.....	19
A. 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Endurance Tests.....	19
B. LD/LDT-465 Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests.....	28
C. LD-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests.....	29
D. LDT-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests.....	29
E. Relationships Between Variables.....	31
V. CONCLUSIONS.....	33
A. 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Tests.....	33
B. LD-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Tests.....	34
C. LDT-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Tests.....	34
VI. RECOMMENDATIONS.....	35
VII. REFERENCES.....	36

APPENDICES

Page

A-6V53T ENG 240-HR TRACK CYCLE TEST 2 (AL-6856-L).....	A-1
B-6V53T ENG 240-HR TRACK CYCLE TEST 4 (AL-6855-L).....	B-1
C-6V53T ENG 240-HR TRACK CYCLE TEST 5 (AL-6947-L).....	C-1
D-6V53T ENG 240-HR TRACK CYCLE TEST 6 (AL-7235-8531-L).....	D-1
E-6V53T ENG 240-HR TRACK CYCLE TEST 7 (AL-8406-L).....	E-1
F-6V53T ENG 240-HR TRACK CYCLE TEST 8 (AL-7172-L).....	F-1
G-6V53T ENG 240-HR TRACK CYCLE TEST 9 (AL-9249-L).....	G-1
H-LD465 ENG 210-HR WHEEL CYCLE TEST 1 (AL-6855-L).....	H-1
I-LD465 ENG 210-HR WHEEL CYCLE TEST 2 (AL-6942-L).....	I-1
J-LD465 ENG 210-HR WHEEL CYCLE TEST 3 (AL-7288-L).....	J-1
K-LD465-1C ENG 210-HR WHEEL CYCLE TEST 4 (AL-8980-L).....	K-1
L-LD465-1C ENG 210-HR WHEEL CYCLE TEST 5 (AL-8924-L).....	L-1
M-LDT465-1C ENG 210-HR WHEEL CYCLE TEST 6 (AL-9249-L).....	M-1

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1	New Properties of Test Lubricants.....8
2	Army Vehicles Powered by Teledyne Continental Motors LD/LDS/LDT-465 Engines.....11
3	Army Tactical Vehicles Powered by GMC Detroit Diesel Two-Cycle Engines.....12
4	Army/CRC 240-Hour Tracked-Vehicle Endurance Cycle.....13
5	Army/CRC 210-Hour Wheeled-Vehicle Endurance Cycle.....14
6	Test Instrumentation.....15
7	6V-53T Engine 240-Hour Tracked-Vehicle Cycle Oil Adjustments and Sampling Schedule.....16
8	Typical Analysis of Test Fuel Caterpillar 1H2/1G2 Reference Fuel (AL-9488-F).....17
9	LD/LDT-465 Engine 210-Hour Tracked-Vehicle Cycle.....17
10	Summary of the Tests Conducted for the Multiviscosity-Grade Diesel Engine Oil Development Program.....20
11	Summary of 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Endurance Test Results.....21
12	Summary of 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Endurance Test Results as a Percentage of Lubricant A OE/HDO-30 Test Results.....22
13	Summary of LD-465-1 Engine 210-Hour Wheeled-Vehicle Cycle Test Results.....23
14	Summary of LD-465 Engine 210-Hour Wheeled-Vehicle Cycle Test Results as a Percentage of Lubricant B OE/HDO-10 Borderline Test Results.....23
15	Summary of LDT-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Test Results.....24
16	Summary of LDT-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Tests Results as a Percentage of Lubricant A OE/HDO-30 Test Results.....25
17	Wear-Related Correlations Between Variables for the 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Tests.....32

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
1	Specifications and Installation of the Detroit Diesel 6V-53T Engine.....9
2	Specifications and Installation of the Teledyne Continental Motors LD-465-1 and LDT-465-1C Engine.....10
3	Average Performance Percentages for the 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Tests.....28
4	Survey of Recommended Ambient Temperature and Lubricant Viscosity Ranges.....30

I. INTRODUCTION

The current military lubrication orders (LO's) for Army combat/tactical vehicle engines, except in Arctic conditions, specify the use of single-viscosity-grade engine oils qualified under MIL-L-2104C.^{(1)*} The viscosity grades specified are 10, 30, 40, and 50 (Military equivalents to SAE 10W-20, 30, 40, and 50, respectively), with the proper grade of oil used dependent on ambient temperature.

Using single-grade engine oils results in frequent changes of still usable oil solely due to changes in ambient temperature, and not to any degradation of the oil. A multiviscosity-grade oil for year-round use would eliminate seasonal oil changes and result in (1) considerable saving on oil used, (2) a reduced number of stock items and associated logistical simplification, (3) a reduced number of engine failures due to the wrong viscosity grade being used, (4) a reduction in maintenance costs, and (5) an increase in equipment readiness.

The Army's high-output diesel engines typically have different operating cycles than the diesel engine used in commercial highway applications. Prolonged periods of wide-open throttle, alternating with relatively long periods of inactivity are more typical of Army use than continuously loaded commercial highway driving. To further compound the difference between commercial highway use and Army operations, the Army engines typically have a higher power output than their civilian counterparts and are operated in vehicles that often have marginal cooling systems due to the overriding requirements for armored protection. As a result, outside of Arctic conditions, commercially available multigrade engine oils have not been used in Army combat/tactical vehicles because of excessive wear and deposits that have resulted from their use.⁽²⁾

In the Arctic, the Army is currently using synthetic-based engine oils qualified under MIL-L-46167⁽³⁾ in ambient temperatures from -55°C to +5°C.

* Superscript numbers in parentheses refer to the list of references at the end of this report.

Their use in combat/tactical vehicles under these conditions has been very successful and has served as an indicator that the use of multigrade diesel engine oils at higher ambient temperatures may be possible.

Because the effectiveness of multigrade diesel engine oils for Army combat/tactical vehicles has been demonstrated in Arctic conditions, the decision was made to develop requirements for a multigrade diesel engine oil for Army tactical vehicles operating in ambient temperatures from -10°C to $+50^{\circ}\text{C}$. A letter was sent to various lubricant and additive manufacturers soliciting help in the development of "a new generation of engine lubricants designed for use in military ground equipment."⁽⁴⁾ This letter resulted in several candidate oils being sent to U.S. Army Mobility Equipment Research and Development Command (MERADCOM) for evaluation. These oils have been evaluated in this program to determine the acceptability of multiviscosity-grade lubricants for use in combat/tactical diesel engines, and to establish performance under future lubricant specification MIL-L-2104D.

II. OBJECTIVE AND SCOPE

The objective of this project was to test seven multiviscosity engine oils for suitability in MIL-L-2104 oil applications. Candidate oils were to meet or exceed the performance level of selected MIL-L-2104C reference oils. This work thus furthers the research needed to develop requirements for a new MIL-L-2104D specification covering multiviscosity combat/tactical diesel engine oils. The scope of the work encompasses the testing of the seven candidate oils and reference oils, evaluation of the candidate oils in comparison to the reference oils, and recommendations for action and further tests. The scope does not include the field testing necessary to corroborate laboratory engine tests.

III. EXPERIMENTAL PROCEDURES

A. Test Lubricants

The inspection properties of the nine different diesel engine lubricants

evaluated during this program are shown in Table 1. Lubricant A is the U.S. Army MIL-L-2104C qualified OE/HDO-30 reference oil. This oil has petroleum basestocks and a calcium-based detergent-dispersant additive package with a sulfated ash content of 1.6 wt%. Lubricant B is the OE/HDO-10 grade of the Army's MIL-L-2104C qualified reference oil and has the same additive chemistry as Lubricant A. Lubricant C, a 10W-30 experimental product, contains a basestock blend of polyalkylated benzenes and mineral oil, and a calcium/magnesium detergent-dispersant additive system with a sulfated ash content of 1.2 wt%. Lubricant D is an experimental 10W-30 mineral oil which contains a magnesium/calcium additive system with a sulfated ash content of 1.1 wt%. Lubricant E is an experimental 10W-30 product which contains a basestock blend of polyalphaolefins and polyolester. The additive system of Lubricant E is calcium based with a sulfated ash content of 1.1 wt%. Lubricant F is a commercially available 15W-40 mineral oil and contains a magnesium/calcium additive system with a sulfated ash content of 1.0 wt%. Lubricant G is also a commercially available 15W-40 mineral oil with a sulfated ash content of 1.0 wt%; however, its detergent-dispersant package is calcium based. Lubricant H is an experimental 10W-30, which contains both synthetic and petroleum basestocks, with a calcium additive system and a sulfated ash content of 1.0 wt%. Lubricant I is an experimental 10W-30 product consisting of a synthetic hydrocarbon and ester basestock blend, with a calcium additive system and a 1.5 wt% sulfated ash. The complete inspection properties of these lubricants are shown in Table 1.

B. Test Engines

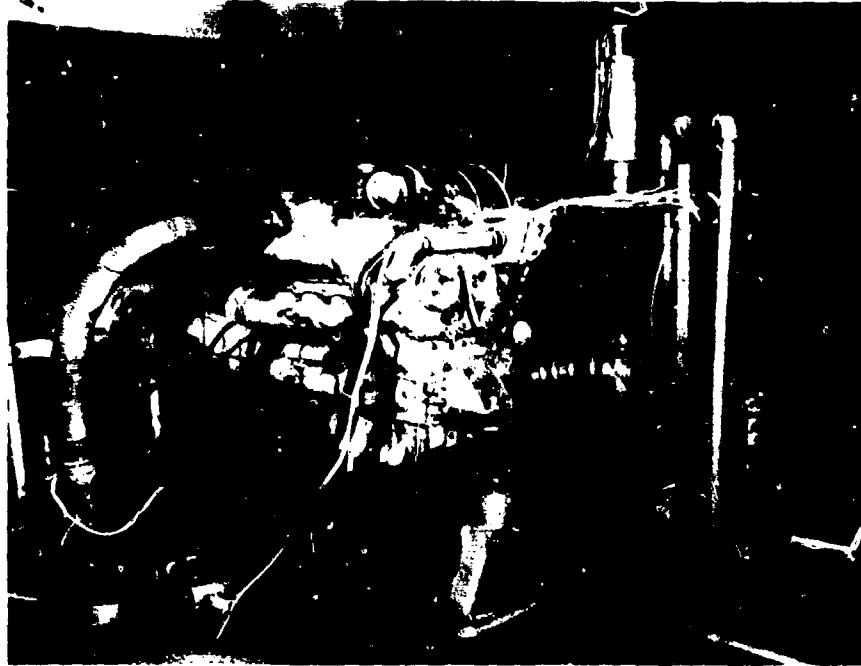
The diesel engines chosen for these multigrade engine oil evaluations were the two-cycle Detroit Diesel 6V-53T engine (Figure 1) and the four-cycle Teledyne Continental Motors LD-465-1 and LDT-465-1C engines (Figure 2).

These engines are representative of many of the same type the Army uses (Tables 2 and 3) and were chosen for test engines because both are "sensitive" to lubricants in different ways. The 6V-53T engine is intolerant of low viscosity combined with high volatility in a lubricating oil, and will severely score cylinders and burn rings if volatility is outside a critical limit.⁽⁵⁾

TABLE I. NEW PROPERTIES OF TEST LUBRICANTS

Property	ASTM Method	Lubricant Designation							
		A	B	C	D	E	F	G	H
SAE Viscosity Grade		30	10W	10W-30	10W-30	10W-30	15W-40	15W-40	10W-30
Apparent Viscosity at -29°C, cP	D 2602	Solid	12250	9000	10500	3200	23000	23000	8500
Apparent Viscosity at -18°C, cP	D 2602	1000	2180	2180	1760	1600	4200	3900	1800
Apparent Viscosity at 40°C, cSt	D 445	107	47	69	66	56	113	97	82
Kinematic Viscosity at 100°C, cSt	D 445	11.6	6.5	10.6	10.5	10.0	14.8	13.9	12.8
Kinematic Viscosity at 100°C, cSt	D 445	96	103	146	146	167	135	146	156
Viscosity Index	D 2270	2.3	2.5	2.5	2.1	3.0	1.9	3.3	2.0
Total Acid Number, mg KOH/g	D 664	13.9	12.7	8.6	10.3	6.3	8.2	6.5	9.1
Total Base Number, mg KOH/g	D 2896	0.03	0.02	0.02	0.01	0.04	0.02	0.01	0.01
Pentane B Insolubles, wt%	D 893	MD	MD	MD	MD	MD	MD	MD	MD
Toluene B Insolubles, wt%	D 893	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.02
Benzene B Insolubles, wt%	D 92	223	214	228	202	224	210	209	221
Flash Point, °C	D 97	-17	-31	-28	-31	-45	-30	-32	-39
Pour Point, °C	D 287	25.5	28.3	29.9	29.2	31.2	28.1	29.3	31.7
Gravity, °API	D 52	2.1	1.7	1.2	1.2	1.1	1.0	1.2	1.2
Carbon Residue, wt%	D 874	1.6	1.7	1.2	1.1	1.1	1.0	1.0	1.0
Sulfated Ash, wt%									
Elements, wt%	Method								
Mg	AA	0.003	0.002	0.07	0.09	0.000	0.13	0.003	0.002
P	XRF	0.11	0.11	0.11	0.10	0.13	0.12	0.13	0.08
S	XRF	0.48	0.43	0.39	0.58	0.33	0.65	0.37	0.27
Ca	AA	0.46	0.46	0.22	0.10	0.25	0.10	0.26	0.24
Zn	AA	0.08	0.09	0.14	0.13	0.13	0.12	0.17	0.11
Ba	AA	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Na	CLM	0.07	0.07	0.04	0.17	0.14	0.12	0.15	0.13
Cl	AA	0.001	0.002	0.000	0.000	0.001	0.002	0.000	0.07
	AA	<0.01	<0.01	<0.01	<0.01	<0.02	<0.02	<0.01	<0.01
AL Code		8980	6855	6947	8531	8924	7172	9249	7288
		6856	OE/HDO-10		7235	8406			
		OE/HDO-30							6942

MD = Not Determined
CLM = Chemiluminescent Method
AA = Atomic Absorption
XRF = X-Ray Fluorescence



6V-53T ENGINE SPECIFICATIONS

Engine Type	Turbocharged, Direct Injection Uniflow Scavenged, Two-Cycle Compression Ignition
No. of Cylinders, arrangement	6, V
Displacement, liters (in. ³)	5.2(318)
Bore x Stroke, mm (in.)	98.43 x 114.30 (3.875 x 4.500)
Rated Power, kW (Bhp)	224(300) @ 2800 rpm, 15.5°C (60°F) and 29.82 in. Hg
Rated Torque, Nm (ft.-lb)	834(615) @ 2200 rpm
Oil Capacity, liters (gal.)	19(5)
Piston Material, Design	Cast Iron, Trunk-Type

FIGURE 1. SPECIFICATIONS AND INSTALLATION OF THE
DETROIT DIESEL 6V-53T ENGINE



LD-465-1 AND LDT-465-1C
ENGINE SPECIFICATIONS

Engine Type	Naturally Aspirated LDT-465-1C is turbocharged), Direct Injection Four-Cycle, Compression Ignition M.A.N. Combustion Chamber Design
Fuel	Multifuel Capability
No. of Cylinders, arrangement	6, in-line
Displacement, liters (in. ³)	7.8(478)
Bore x Stroke, mm (in.)	115.8 x 123.7 (4.56 x 4.87)
Rated Power, kW (Bhp)	104(140) @ 2600 rpm,
Oil Capacity, liters (gal.)	21(5.5)

FIGURE 2. SPECIFICATIONS AND INSTALLATION OF THE
TELEDYNE CONTINENTAL MOTORS LD-465-1 AND LDT-465-1C ENGINES

TABLE 2. ARMY VEHICLES POWERED BY TELEDYNE CONTINENTAL
MOTORS LD/LDS/LDT-465 ENGINES*

Designation	Description	Engine Model
M44A2	Chassis, Truck: 6x6	LD-465-1
M45A2	Chassis, Truck: 6x6	LD-465-1
M45A2G	Chassis, Truck: 6x6	LD-465-1
M46A2C	Chassis, Truck: 6x6	LD-465-1
M621	Chassis, Truck: 6x6	LD-465-1
M622	Chassis, Truck: 6x6	LD-465-1
M623	Chassis, Truck: 6x6	LD-465-1
M624	Chassis, Truck: 6x6	LD-465-1
M40A2	Chassis, Truck: 6x6	LDS-465-1A
M40A2C	Chassis, Truck: 6x6	LD-465-1A
M63A2	Chassis, Truck: 6x6	LDS-465-1A
M63A2C	Chassis, Truck: 6x6	LDS-465-1A
M35A2	Truck, Cargo: 6x6	LD-465-1
M35A2C	Truck, Cargo: 6x6	LD-465-1
M36A2	Truck, Cargo: 6x6	LD-465-1
M621	Truck, Cargo: 6x6	LD-465-1
M54A2C	Truck, Cargo: 6x6	LD-465-1A
M55A2	Truck, Cargo: 6x6	LD-465-1A
M656	Truck, Cargo: 8x8	LD-465-(TC)
M342A2	Truck, Dump: 6x6	LD-465-1
M624	Truck, Dump: 6x6	LD-465-1
M51A2	Truck, Dump: 6x6	LD-465-1A
M49A2C	Truck, Tank: Fuel, 6x6, 4542 L (1200 gal.)	LD-465-1
M50A2	Truck, Tank: Water, 6x6, 3785 L (1000 gal.)	LD-465-1
M622	Truck, Tank: Fuel Servicing, 6x6, 4542 L (1200 gal.)	LD-465-1
M275A2	Truck, Tractor: 6x6	LD-465-1
M52A2	Truck, Tractor: 6x6	LD-465-1A
M246A2	Truck, Tractor: Wrecker, 6x6	LDS-465
M109A3	Truck, Van: Shop, 6x6	LD-465-1
M185A2	Truck, Van: Shop, 6x6	LDS-427-2
M185A3	Truck, Van: Shop Repair, 6x6	LD-465-1
M623	Truck, Van: Shop, 6x6	LD-465-1
M291A2	Truck, Van: Expansible, 6x6	LDS-465-1A
M291A2C	Truck, Van: Expansible, 6x6	LDS-465-1A
M543A2	Truck, Wrecker: Medium, 6x6	LDS-465-1A

* Source: TM 43-0001-31, Equipment Data Sheets for TARCUM Equipment,
July 1978.

Note: The LDT-465-1C engine is used interchangeably in vehicles utilizing
the LD-465-1 engine.

TABLE 3. ARMY TACTICAL VEHICLES POWERED BY GMC DETROIT DIESEL
TWO-CYCLE ENGINES

<u>Designation</u>	<u>Description</u>	<u>Engine Model</u>
M106A1	Mortar, Self-propelled, 107 mm	6V-53
M107	Gun, Self-propelled, 175 mm	8V-71T
M108	Howitzer, Self-propelled, 105 mm	8V-71T
M109	Howitzer, Medium, 155 mm	8V-71T
M110	Howitzer, Self-propelled	8V-71T
M113A1	Carrier, Personnel	6V-53
M125A1	Mortar, Self-propelled, Full-tracked	6V-53
M132A1	Flame Thrower, Self-propelled	6V-53
M548	Carrier, Cargo, Tracked	6V-53
M551	Armored Reconnaissance/Airborne Assault Vehicle (Sheridan)	6V-53T
M561	Gamma Goat	3-53
M577A1	Carrier, Command Post, Light-tracked	6V-53
M578	Recovery Vehicle	8V-71T
HET70	Heavy Equipment Transporter	12V-71T
XM 667	Carrier, GM, Equipment, SP	a
XM 727	Carrier, GM, Equipment, SP	a
XM 730	Carrier, GM, Equipment, SP	a
XM 741	Chassis, Gun, AA Artillery, 20 mm, SP	a
XM 806E1	Recovery Vehicle, FT Armored	a
---	Truck, Dump, Diesel Electric Driven	6V-71
M911	Heavy Equipment Transporter	8V-92T

a - Vehicles are powered by either 6V-43, 6V-53T, or 8V-71T (TB-750-652).

The LD-465 engine family will increase the viscosity of some lubricants so that at low temperatures, cranking, starting-and-running, lubricant pumpability, and subsequent lack of lubrication are potential problems. In addition, the LD-465 engine family produces high blowby which stresses the lubricant additive package.

C. Test Cycles

The endurance test cycle chosen for the 6V-53T engine was the Army/Coordinating Research Council (CRC) 240-hour Tracked-Vehicle Cycle (Table 4), which has been correlated to 6437 kilometers (4000 miles) of proving ground

TABLE 4. ARMY/CRC 240-HOUR TRACKED-VEHICLE ENDURANCE CYCLE

<u>Period*</u>	<u>Time, hr</u>	<u>Rack/Throttle Setting</u>	<u>Coolant Jacket-Out Temp, °C(°F)</u>
1	0.5	idle	38(100)
	2.0	Maximum Power**	77(170)
	0.5	idle	38(100)
	2.0	Maximum Torque**	77(170)
2	0.5	idle	38(100)
	2.0	Maximum Power	77(170)
	0.5	idle	38(100)
	2.0	Maximum Torque	77(170)
3	0.5	idle	38(100)
	2.0	Maximum Power	77(170)
	0.5	idle	38(100)
	2.0	Maximum Torque	77(170)
4	0.5	idle	38(100)
	2.0	Maximum Power	77(170)
	0.5	idle	38(100)
	2.0	Maximum Torque	77(170)
5	4	5 min idle, followed by shutdown	---

*These five periods yield 20 hours of running with a 4-hour shutdown; this cycle is repeated 12 times for a total test time of 240 hours.

**For the 6V-53T, Maximum Power occurs at 2800 rpm and Maximum Torque occurs at 2200 rpm.

operation.⁽²²⁾ The endurance test cycle chosen for the LD/LDT-465-1 engines was the Army/CRC 210-hour Wheeled-Vehicle Cycle (Table 5), which has been correlated to 32,187 kilometers (20,000 miles) of proving ground operation.⁽²²⁾

TABLE 5. ARMY/CRC 210-HOUR WHEELED-VEHICLE ENDURANCE CYCLE

<u>Period*</u>	<u>Time, hr</u>	<u>Rack/Throttle Setting</u>	<u>Coolant Jacket-Out Temp, °C(°F)</u>
1	2	5 min idle followed by slow acceleration to maximum power**	82(180)
2	1	idle	38(100)
3	2	Maximum Power	82(180)
4	1	idle	38(100)
5	2	Maximum Power	82(180)
6	1	idle	38(100)
7	2	Maximum Power	82(180)
8	1	idle	38(100)
9	2	Maximum Power	82(180)
10	10	5 min idle followed by shutdown	---

* These 10 periods yield 14 hours of running with a 10-hour shutdown; this cycle is repeated 15 times for a total test time of 210 hours.

** For the LD-465 series engines, Maximum Power occurs at 2600 rpm.

D. Test Procedures

1. 6V-53T Engine--Prior to each endurance test, the 6V-53T engine was disassembled and rebuilt. New cylinder assemblies (which include piston, rings, and piston pin) were used for each rebuild, and the connecting rod bushings, connecting rod bearings, camshaft bearings, and main bearings were replaced only if the clearances were out of specification, or if appearance warranted replacement. The combustion chambers were cleaned by wire brushing, and the exhaust valves were refaced or replaced as necessary, and lightly

lapped. The manufacturer's rebuild specifications^(23,24) were followed for all parts, and particular attention was given to all measurements and operations involving the cylinder assemblies, the main indicators of lubricant performance in this engine test.

Prior to each test, the instrumentation (Table 6) was recalibrated, with particular attention given to the tachometer, flowmeter, and dynamometer load system. After calibration the engine was broken in, and a before-test power curve at full-rack from 1800 to 2800 rpm at 200 rpm increments was run. The 240-hour Tracked-Vehicle Cycle Endurance Test was then run, with an oil change at 120 hours.

TABLE 6. TEST INSTRUMENTATION

Midwest Eddy Current Dynamometer, Type MW10K, 298 kW(400 hp) absorbing, 1500-5000 rpm.

Newport Digital Tachometer, Model 6130A, 0-10000 rpm.

Flotron Fuel Flowmeter, Part No. 10E48, 0-91 Kg (0-200 lb/hr).

Hagan Pneumatic Load Cell w/Wallace and Tiernen Readout, 0-499 Kg (0-1100 lb).

Honeywell Temperature Recorder, Model 153C64P2-228W7-42, -17.8°-537.8°C(0°-1000°F).

Moore Temperature Controller, Model 5311MT2(M2), 37.8°-121°C(100°-250°F).

Various Crosby and Helicoid Bourdon Tube Pressure Gauges, 0-30, 0-60, 0-100 psig.

King Manometer, Model AF5FF24, 0-635 mm(0-25 in).

Meriam Inclined Manometer, Model M177, 0-102 mm(0-4 in).

Omega Exhaust Thermocouple Readout, -17.8°-1093°C(0°-2000°F).

LD-465-1, LDT-465-1C Engines

Dynatomic Eddy Current Dynamometer, Model C-50-U, 244 kW(300 hp) absorbing 2100-5000 rpm.

Newport Digital Tachometer, Model 6130A, 0-10000 rpm.

Flowtron Fuel Flowmeter, Part No. 10E48, 0-91 kg/hr(0-200 lb/hr).

Tate-Emery Hydraulic-Pneumatic Load System, 0-227 kg(0-500 lb).

Honeywell Temperature Recorder Model 153X72-P16-II-III-6, -17.8°-315.6°C(0°-600°F).

Moore Temperature Controller, Model 5311MT2, 37.8°-121°C(100°-250°F).

Various Crosby Bourdon Tube Pressure Gauges, 0-15, 0-60, 0-100, 0-160 psig.

King Manometer, Model AF5FF24, 0-635 mm(0-25 in).

Meriam Inclined Manometer, Model 40HE35, 0-102 mm(0-4 in).

Omega Exhaust Thermocouple Readout, -17.8°-1093°C(0°-2000°F).

Oil samples were taken for chemical and physical analysis, oil additions were made, and the airbox was inspected according to the schedule in Table 7.

TABLE 7. 6V-53T ENGINE 240-HOUR TRACKED-VEHICLE CYCLE
OIL ADJUSTMENTS AND SAMPLING SCHEDULE

Operation	Test Hours												
	0	20	40	60	80	100	120	140	160	180	200	220	240
Oil Adjustments	-	X	X	X	X	X	X	X	X	X	X	X	-
Used Oil Sampled	-	X	X	*	X	X	*	X	X	*	X	X	*
Airbox Inspected	X	-	-	X	-	-	X	-	-	X	-	-	-
Oil Change	X	-	-	-	-	-	X	-	-	-	-	-	-

X indicates adjustment, sampling, or inspection to be performed at given test time.

* indicates 0.94-L (32-oz.) samples.

After the endurance test was completed, an after-test power curve at full-rack from 1800 to 2800 rpm at 200 rpm increments was run. The engine was then disassembled and the same components measured before the test were remeasured, with particular attention given to the piston ring end gap and the cylinder liner inside diameter. Next, the engine was rated for deposits, according to applicable Coordinating Research Council (CRC) rating methods for diesel engines.^(25,26) Then photographs of the pistons, rings, cylinders, combustion chambers, and any unusual parts were taken. The engine was then rebuilt for the next test. The test fuel for all tests was Caterpillar 1H2/1G2 Reference Fuel⁽²⁷⁾ (0.4 wt% sulfur), with a typical analysis shown in Table 8.

2. LD-465-1 and LDT-465-1C Engines--The rebuilding and testing of the LD-465-1 and LDT-465-1C engines generally followed the same procedures as the 6V-53T tests. Exceptions were the following: the 210-hour Wheeled-Vehicle Cycle was used (oil sampling and addition schedule given in Table 9); before-test and after-test power curves were from 1200 to 2600 rpm at 200 rpm increments; and photographs of the intake and exhaust valves were taken. The test fuel for these tests was also Caterpillar 1H2/1G2 reference fuel.

TABLE 8. TYPICAL ANALYSIS OF TEST FUEL CATERPILLAR 1H/1G REFERENCE
FUEL (AL-9488-F)

Property	ASTM Method	Specification Requirements*	Analysis
<u>Distillation, °C(°F)</u>	D 86		
Initial Boiling Point		Report	207(405)
10% recovered		Report	241(465)
50% recovered		500 min.	273(524)
90% recovered		600-640	317(602)
End Point		650-690	348(658)
Recovery, vol%		NR	99.0
Residue, vol%		NR	1.0
Loss, vol%		NR	0.0
Flash Point, °C(°F)	D 93	100 min	86(187)
Cloud Point, °C(°F)	D 2500	Report	-2(28)
Pour Point, °C(°F)	D 97	20 max	-12(10)
Viscosity at 38°C(100°F), cSt	D 445	1.6-4.5	3.3
Neutralization No., mg KOH/g	D 664	NR	0.0
Water & Sediment, vol%	D 1796	0.05 max	0.0
Cetane Number	D 613	40-45	52
Gravity, °API	D 287	Report	34.5
Net Heat of Combustion, J/kg	D 240	Report	42.13x10 ⁶
(Btu/lb)			(18130)
Sulfur, wt%	D 1552	0.35 min	0.404
Carbon Residues on 10% Bottoms, wt%	D 524	0.20 max	0.10
Copper Strip Corrosion, 2 hr at 50°C(122°F)	D 130	No. 2 max	1A

*See Reference 27.

NR = Not required.

TABLE 9. LD/LDT-465 ENGINE 210-HOUR TRACKED-VEHICLE CYCLE

Operation	Test Hours													
	14	28	42	56	70	84	98	112	140	154	168	182	196	210
Oil Adjustments	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Used Oil Sampled	X	X	X	X	*	X	X	X	*	X	X	X	X	*

X indicates adjustment, sampling, or inspection to be performed at given test time.

* indicates 0.94-L (32-oz) samples.

E. Test Evaluation

The results of the multigrade oil tests were evaluated by comparison with single-grade OE/HDO-30 or OE/HDO-10 test results using the same engine and test cycle. These two MIL-L-2104C lubricants were chosen because the OE/HDO-30 oil has shown good performance in the 6V-53T engine in the field. The OE/HDO-10 oil would be expected to show the cylinder liner scoring and ring burning in the 6V-53T engine that the low viscosity/high volatility MIL-L-2104B predecessors have shown.⁽²⁷⁾ With this information as the basis, the OE/HDO-30 endurance test results were designated acceptable performance level and the OE/HDO-10 endurance test results were designated borderline fail.

The criteria chosen for the comparative evaluations were a combination of lubricant physical and chemical properties and engine condition (mainly wear and deposits). For the 6V-53T engine tests, more attention was given to engine condition than to lubricant analyses, while for the LD/LDT-465 engine tests more attention was given to lubricant analyses than to engine condition. Although engine condition and lubricant analyses are important for both tests, favoring either engine condition or lubricant analyses indicates the main area of lubricant concern for that engine as well as the importance of the data obtained.

For example, in the LD/LDT-465 engine tests the cylinder liner diameter increase and piston ring end gap increase did not vary much between tests. The cylinder liner diameter increase for all tests varied from 0.00254 to 0.0127 mm (0.0001 to 0.0005 in.). Changes of this magnitude are at the limits of the measuring instruments used and are of the same magnitude as changes in diameter due to changes in ambient temperature of 10° to 30°F, which commonly occur. For a 102-mm (4-in.) diameter cylinder, and a 30°F change in temperature between measurements, a change in diameter of 0.00254 mm (0.0001 in.) solely due to temperature will occur, using 12×10^{-6} meters per meter of length per °C (6×10^{-6} in./in./°F) as the coefficient of thermal expansion for cast iron. Similarly the piston ring end gap increases did not vary between tests by more than 0.051 mm (0.002 in.), near the limits of the mea-

asuring instrument for this measurement also. As a result, the main test evaluation criteria for the LD/LDT-465 engine tests were the lubricant properties.

While the 6V-53T engine experienced a similar magnitude of ambient temperature changes and measurement limits, the changes in cylinder liner diameter and piston ring end gap increase were greater than those found in the LD/LDT engine. This decreased the errors in measurement due to temperature changes and instrument limits. In addition, the lubricant properties, over the span of one endurance test, did not vary nearly as much in the 6V-53T engine as they did in the LD/LDT-465-1 engine. So for the 6V-53T engine tests, the main test evaluation criteria were the engine conditions.

A summary of the tests conducted during this program is given in Table 10. Complete test result summaries are listed in Appendices A through M.

III. DISCUSSIONS OF RESULTS

The following discussion is based mainly on the summarized data in Tables 11 and 12 for the 6V-53T engine; in Tables 13 and 14 for the LD-465-1 engine; and in Tables 15 and 16 for the LDT-465-1C engine. The data in Tables 12, 14, and 16 compare with the data of Tables 11, 13, and 15, respectively, with the latter expressed as a percentage of the baseline oil test results for ease of comparison.

A. 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Endurance Tests

A summary of the test results considered important in determining lubricant performance is given in Tables 11 and 12.

Cylinder liner diameter increase, piston ring gap increase, liner scuffing, liner glazing, and ring face scuffing are important. Large amounts of any of these parameters can cause reduced power output, increased fuel consumption, reduced engine life, increased oil consumption, and fuel dilution of the oil,

TABLE 10. SUMMARY OF THE TESTS CONDUCTED FOR THE MULTIVISCOSITY-GRADE
DIESEL ENGINE OIL DEVELOPMENT PROGRAM

6V-53T Engine 240-Hour Tracked-Vehicle Cycle Endurance Tests

<u>Test No.</u>	<u>Lubricant Designation</u>	<u>SAE Viscosity Grade</u>	<u>Lubricant Basestock</u>
3	A	30	Mineral
4*	B	10W	Mineral
5	C	10W-30	Polyalkylated Benzenes + Mineral
6	D	10W-30	Mineral
7	E	10W-30	Polyalphaolefins (PAO) + Polyol Ester
8	F	15W-40	Mineral
9	G	15W-40	Mineral

LD-465-1 Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests

<u>Test No.</u>	<u>Lubricant Designation</u>	<u>SAE Viscosity Grade</u>	<u>Lubricant Basestock</u>
1	B	10W	Mineral
2	I	10W-30	Synthetic hydrocarbon + ester
3	H	10W-30	Mineral + Synthetic

LDT-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests

<u>Test No.</u>	<u>Lubricant Designation</u>	<u>SAE Viscosity Grade</u>	<u>Lubricant Basestock</u>
4	A	30	Mineral
5	E	10W-30	Polyalphaolefins (PAO) + Polyol Ester
6	G	15W-40	Mineral

* Test stopped at 140 hours due to severe scoring of cylinder 1L.

TABLE 11. SUMMARY OF 6V-53T ENGINE 240-HOUR TRACKED-VEHICLE CYCLE ENDURANCE TEST RESULTS

	*Test No. 3 SAE 30	**Test No. 4 SAE 10W	Test No. 5 SAE 10W-30	Test No. 6 SAE 10W-30	Test No. 7 SAE 10W-30	Test No. 8 SAE 15W-40	Test No. 9 SAE 15W-40
	A	B	C	D	E	F	G
Avg. Engine Condition							
Cylinder Liner Diameter Increase, cm	0.003 (0.0012)	0.003 (0.0012)	0.004 (0.0015)	0.004 (0.0015)	0.003 (0.0011)	0.003 (0.0011)	0.001 (0.0002)
(in.)							
Piston Ring End Gap Increase, cm	0.010 (0.004)	0.023 (0.009)	0.023 (0.009)	0.036 (0.014)	0.015 (0.006)	0.008 (0.003)	0.010 (0.004)
(in.)	18	38	34	33	22	11	11
Cylinder Liner Scuffing, % area	21	10	10	5	14	9	13
Cylinder Liner Glazing, % area	33	67	65	65	26	16	19
Piston Ring Face Scuffing, % area	369	343	306	308	309	365	349
Piston WTD Deposits, CRC rating							
Piston Ring Groove Carbon	27	25	30	26	24	25	27
Filling, vol%	2	0	1	1	1	1	3
Number of Stuck Rings							
Oil Consumption, kg/hr (lb/hr)	0.30(0.67)	0.30(0.67)	0.17(0.38)	0.31(0.68)	0.21(0.46)	0.33(0.72)	0.32(0.71)
Lubricant Properties							
Apparent Viscosity Increase at -29°C, %	ND	ND	ND	ND	ND	74	89
Apparent Viscosity Increase at -18°C, %	ND	17	ND	65	-13	62	101
Kinematic Viscosity Increase at 40°C, %	40	0	9	6	2	2	26
Kinematic Viscosity Increase at 100°C, %	16	9	1	-1	-5	-6	14
Iron in oil, ppm at end of test by XRF	88	260	250	164	202	56	59
AL Code	6856	6855	6947	7235/8531	8406	7172	9249

* Reference Oil.

** Test 4 (Reference Oil) stopped at 140 hours due to severe scoring of cylinder 1L.

ND = Not Determined.

TABLE 12. SUMMARY OF 6V-53T ENGINE 240-HOUR TRACKED-VEHICLE CYCLE ENDURANCE TEST RESULTS AS A PERCENTAGE OF LUBRICANT A OE/HDO-30 TEST RESULTS*

Avg. Engine Condition	Test 4** SAE 10W B	Test 5 SAE 10W-30 C	Test 6 SAE 10W-30 D	Test 7 SAE 10W-30 E	Test 8 SAE 15W-40 F	Test 9 SAE 15W-40 G
Cylinder Liner Diameter Increase, %	0	+30	+30	-10	-10	-30
Piston Ring End Gap Increase, %	+130	+130	+250	+50	-20	0
Cylinder Liner Scuffing, % RTA	+110	+90	+80	+20	-40	-40
Piston Ring Face Scuffing, %	+100	+100	+100	-20	-50	-40
Piston WTD Deposits, %	-10	-20	-20	-20	0	-10
Piston Ring Groove Carbon Filling, %	-10	+10	0	-10	-10	0
Oil Consumption, %	0	-40	0	-30	+10	+10
Lubricant Properties						
Kinematic Viscosity Increase at 40°C***, %	-100	-80	-90	-100	-100	-40
Kinematic Viscosity Increase at 100°C, %	-40	-90	-100	-130	-130	-10
Iron in the Oil, %	+200	+180	+90	+130	-40	-30
Averaged Performance Percentage, %	+38	+31	+34	-12	-39	-24
AL Code	6855	6947	7235/8531	8406	7172	9249

* The numbers indicate the percent more (+) or less (-) of the given quantity than the acceptable performance level test results. Negative numbers reflect better performance.

** Test 4 stopped at 140 hours due to severe scoring of cylinder 1-left.

*** For viscosity, % increase = [(% increase test oil/% increase acceptable performance level oil)-1] x 100.

RTA = Ring Travel Area.

TABLE 13. SUMMARY OF LD-465-1 ENGINE 210-HOUR WHEELED-VEHICLE
CYCLE TEST RESULTS

<u>Lubricant Properties</u>	Test 1	Test 2	Test 3
	SAE 10W B	SAE 10W-30 I	SAE 10W-30 H
Kinematic Viscosity Increase at 40°C, %	38	61	48
Kinematic Viscosity Increase at 100°C, %	38	42	32
Pentane B Insolubles, wt%, ASTM D 893	5.0	1.3	0.2
Iron in the Oil, ppm by XRF*	263	167	247
<u>Avg. Engine Condition</u>			
Cylinder Liner Diameter Increase,			
cm	-0.0003	-0.0005	0.0006
(in.)	(-0.0001)	(-0.0002)	(-0.0059)
Piston Ring Gap Increase,			
cm	0.008	0.008	0.010
(in.)	(0.003)	(0.003)	(0.004)
Piston WTD Deposit Rating	131	91	112
Intake Valve Tulip Deposit Rating	3.9	2.7	2.9
Oil Consumption, kg/hr (lb/hr)	0.17(0.38)	0.10(0.21)	0.07(0.15)
<u>AL Code</u>	6855	6942	7288

*XRF = X-ray fluorescence.

TABLE 14. SUMMARY OF LD-465 ENGINE 210-HOUR WHEELED-VEHICLE CYCLE TEST
RESULTS AS A PERCENTAGE OF LUBRICANT B OE/HDO-10 BORDERLINE TEST RESULTS*

<u>Lubricant Properties</u>	Test 2	Test 3
	SAE 10W-30 I	SAE 10W-30 H
Kinematic Viscosity Increase at 40°C**, %	+61	+28
Kinematic Viscosity Increase at 100°C, %	+11	-16
Pentane B Insolubles, %, ASTM D 893	-74	-96
Iron in the oil, % by XRF***	-37	-6
<u>Avg. Engine Condition</u>		
Piston Ring Gap Increase, %	0	+33
Piston WTD Deposit Rating, %	-31	-15
Intake Valve Tulip Deposit Rating, %	-31	-26
Oil Consumption, %	-45	-61
Averaged Performance Percentage, %	-18	-20
<u>AL Code</u>	6942	7288

* The numbers indicate the percent more (+) or less (-) of the given quantity than the borderline fail test results.

** For viscosities, % increase = $[(\% \text{ increase test oil} / \% \text{ increase borderline fail oil}) - 1] \times 100$.

*** XRF = X-ray fluorescence.

TABLE 15. SUMMARY OF LDT-465-1C ENGINE 210-HOUR WHEELED-VEHICLE CYCLE TEST RESULTS

Lubricant Properties, End of Test	ASTM Method	Test 4		Test 5		Test 6	
		SAE 30		SAE 10W-30		SAE 15W-40	
		A		E		G	
Kinematic Viscosity Increase at 40°C, %		170		15		86	
Kinematic Viscosity Increase at 100°C, %		100		8		46	
Total Acid Number, mg KOH/g	D 664	6.0		4.4		5.8	
Total Base Number, mg KOH/g	D 2896	5.5		2.3		2.6	
Pentane B Insolubles, wt%	D 893	6.7		2.4		3.2	
Toluene B Insolubles, wt%	D 893	5.3		2.1		2.4	
Carbon Residue, wt%	D 524	7.1		3.1		3.9	
Sulfated Ash, wt%	D 874	3.6		1.8		1.9	
Iron in the Oil, ppm by XRF*		108		252		157	
Avg. Engine Condition		0.0013 (0.0005)		0.0002 (-0.0001)		0.0013 (0.0005)	
Cylinder Liner Diameter Increase, cm (in.)		0.0051 (0.002)		0.0051 (0.002)		0.0051 (0.002)	
Piston Ring End Gap Increase, cm (in.)		274		177		274	
Piston WTD Deposit Rating		3.5		0.4		1.8	
Intake Valve Tulip Deposit Rating		0.34(0.74)		0.16(0.35)		0.17(0.38)	
Oil Consumption, kg/hr(lb/hr)		8980		8924		9249	
AL Code							

*XRF = X-ray fluorescence.

TABLE 16. SUMMARY OF LDT-465-1C ENGINE 210-HOUR WHEELED-VEHICLE CYCLE TEST RESULTS AS A PERCENTAGE OF LUBRICANT A OE/HDO-30 TEST RESULTS

<u>Lubricant Properties</u>	<u>ASTM Method</u>	Test 5	Test 6
		SAE 10W-30 E	SAE 15W-40 G
Kinematic Viscosity Increase at 40°C**, %		-91	-49
Kinematic Viscosity Increase at 100°C, %		-92	-54
Total Acid Number, %	D 664	-27	-3
Total Base Number, %	D 2896	-58	-53
Pentane B Insolubles, %	D 893	-64	-52
Toluene B Insolubles, %	D 893	-60	-55
Carbon Residue, %	D 524	-56	-45
Sulfated Ash, %	D 874	-50	-47
Iron in the Oil, % by XRF***		+133	+45
<u>Avg. Engine Condition</u>			
Cylinder Liner Diameter Increase, %		0	0
Piston Ring End Gap Increase, %		0	0
Piston WTD Deposit Rating, %		-35	0
Intake Valve Tulip Deposit Rating, %		-89	-49
Oil Consumption, %		-53	-49
Averaged Performance Percentage, %		-39	-29
AL Code		8924	9249

* The numbers indicate the percent more (+) or less (-) of the given quantity than the acceptable performance level test results.

** For viscosities, % increase = [(% increase test oil/% increase acceptable performance level oil) - 1] x 100.

*** XRF = X-ray fluorescence.

all due to ineffective gas sealing between the combustion chamber and crankcase. Deposits are important because they can also contribute to ineffective sealing between the combustion chamber and crankcase by causing ring sticking and cylinder liner wear. Deposits can also cause the exhaust valves to stick and burn, resulting in a poor combustion chamber seal.

The lubricant properties of Apparent and Kinematic Viscosity are important because changes in them are indicators of the oxidation, fuel dilution, and soot quantity as well as the stability of the viscosity index (VI) improvers. Oxidation and soot tend to increase the viscosity, while fuel dilution and

shearing of the polymeric VI improvers tend to decrease the viscosity as an oil is used. Areas to check during observation of viscosity change of the oil include ensuring that the oil does not become so viscous that cranking, starting, running, or pumpability is impaired, or becomes thin so that the oil fails to maintain an adequate hydrodynamic film on critical engine components such as bearing and cams.

Since there was only one endurance test run with a given lubricant, the effect of variables on the repeatability and reproducibility of the test results is unknown and can only be estimated.

From the data in Tables 11 and 12, cylinder liner diameter increase was essentially equal for all oils, with the exception of Lubricant G which had roughly 17 percent of the increase of the others. Although the uncertainty due to ambient temperature differences between before and after test measurements remained, the difference in cylinder liner diameter increase between Lubricant A, the OE/HDO-30 and Lubricant G was enough to conclude that cylinder wear was less using Lubricant G.

Piston ring end gap increase was substantially higher for all the oils except the two 15W-40 oils, Lubricant F and Lubricant G, which were equal to the acceptable performance level results. With end gap changes of such magnitude, the errors due to ambient temperature changes were much less, and the changes seen here can be much more confidently attributed to differences in oils. It is worth noting that all the oils with the larger end gap increases are 10W-30 oils, while the two oils with end gap increases equal to the baseline are both 15W-40 oils.

The average cylinder liner scuffing also roughly followed the same trend that the ring gap increase did; the 10W-30 oils had more scuffing than the OE/HDO-30 baseline while the 15W-40 oils had less scuffing than the OE/HDO-30 baseline.

Ring face scuffing was higher than the OE/HDO-30 oil for Lubricant B, C, and D. It was less than the OE/HDO-30 oil for Lubricants E, F, and G. Again,

the two 15W-40 oils performed better than the OE/HDO-30 oil, with one 10W-30, Lubricant E, also doing better than the OE/HDO-30 oil.

Piston Weighted Total Deposits (WTD) ratings, ring groove carbon filling, and number of stuck rings were essentially equal for all oils tested, leading to the conclusions that either all these oils had similar deposit-forming tendencies, or the test was unable to discriminate between oils in this respect.

Oil consumption was also roughly equal for all oils tested, except for Lubricant C and Lubricant E, which had 60 and 70 percent of the oil consumption of the OE/HDO-30 oil, respectively.

The kinematic viscosity increases at 40° and 100°C were less for all oils tested, with Lubricants D, E, B, and F performing the best.

The apparent viscosity increases at -29° and -18°C cannot be compared to acceptable performance level oil test results since viscosities at these temperatures were not obtained for the OE/HDO-30 oil (SAE 30 grade does not flow at these temperatures). However, comparisons between the different test oils show that Lubricant E had the least increase (actually a 13 percent decrease) of all oils, with Lubricant B next.

The amount of iron in the oil, an indicator of wear, was substantially more for all oils tested except the two 15W-40 oils, Lubricant F and Lubricant G.

The averaged performance percentage (APP) is the average of all the performance figures for a given oil. For all of the quantities in Table 11, a more positive (+) value is worse, so that the more negative (-) a value is, the better. Lubricant F has the best APP at -39 percent, indicating that overall it performed substantially better than the OE/HDO-30 baseline. Lubricant G was next at -24 percent APP, also substantially better than the OE/HDO-30 baseline. The next APP was Lubricant E, just slightly better overall than the baseline. Lubricants C, D, and B with APP ratings of 31, 34, and 38 percent, respectively, were alike in that all were substantially worse overall than the OE/HDO-30 oil.

Figure 3 graphically represents these APP results and shows that Lubricants G, F, and E all performed better than the OE/HDO-30, while Lubricants C, D, and B all performed worse.

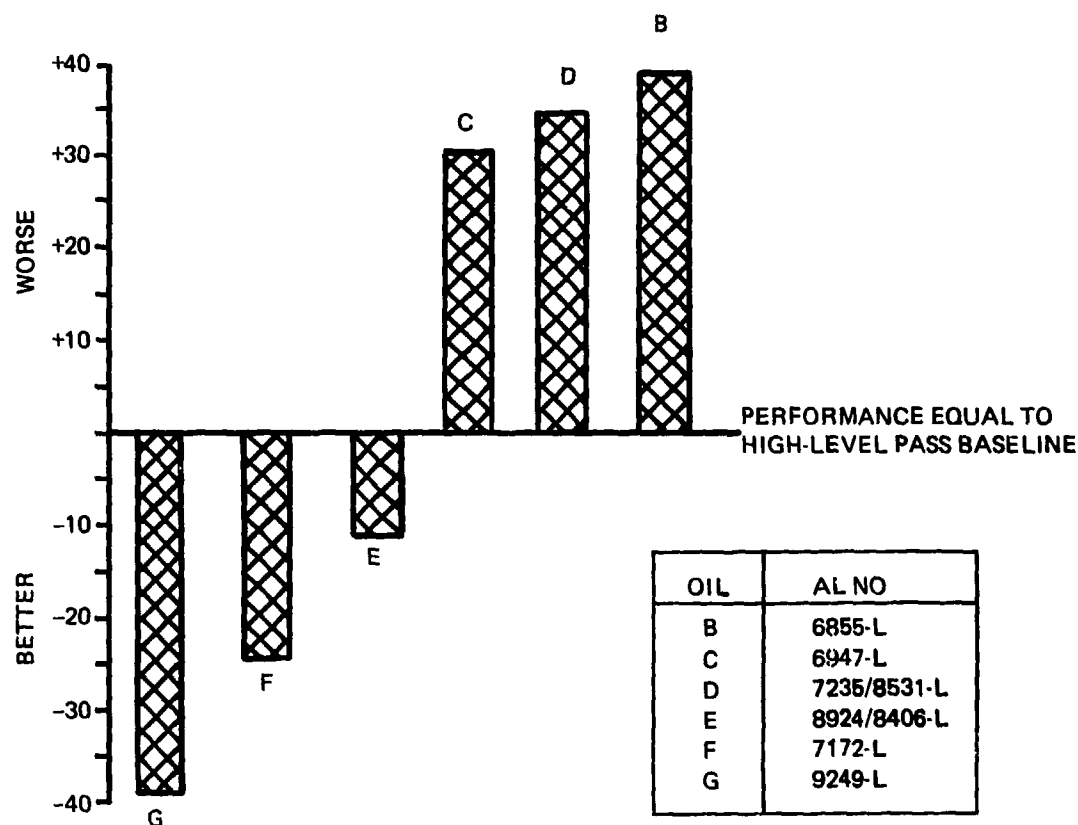


FIGURE 3. AVERAGE PERFORMANCE PERCENTAGES FOR THE 6V-53T ENGINE
240-HOUR TRACKED-VEHICLE CYCLE TESTS

B. LD/LDT-465 Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests

Initially, the LD-465-1 engine configuration was used for these endurance tests, but was later changed to the LDT-465-1C engine turbocharged configuration to make the test more severe than it had been. Since the two types of 465 engines had different operating conditions [LD-465-1 engine maximum power of approximately 99 kW (133 bhp) versus LDT-465-1C engine maximum power of approximately 112 kW (150 bhp)], the test results using one configuration will

be considered separately from the test results of the other configuration. Tables 13 through 16 summarize the LD-465 engine and LDT-465-1C engine test results considered important in determining lubricant performance.

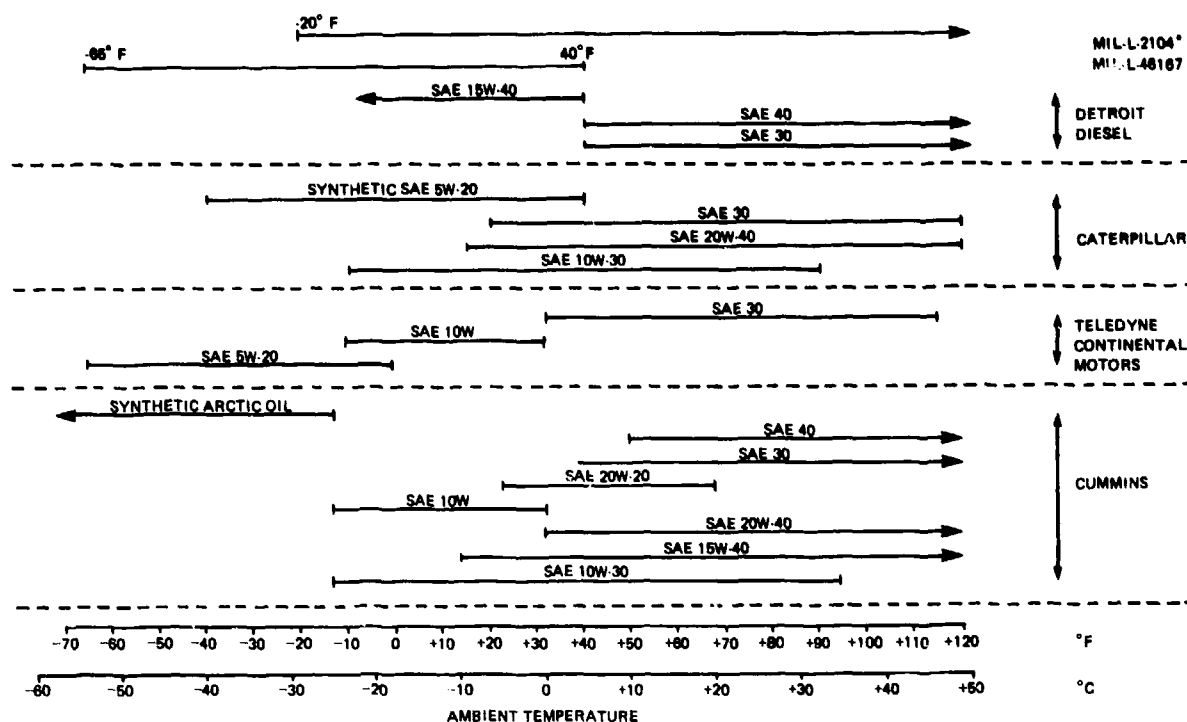
Again, since only one endurance test was run with a given lubricant, the effect of random variables on test results is unknown. Complete data for all tests are given in References 8 through 20.

C. LD-465-1 Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests

From the data in Tables 13 and 14, the kinematic viscosities at 40°C of both oils increased much more than the borderline fail baseline oil. While the borderline fail oil, Lubricant B, was designated so because of its high volatility and subsequent poor performance in the 6V-53T engine, it also was the oil the Army used in low-ambient temperature conditions. Because of this, Lubricant B was a suitable reference oil for low-temperature viscosity increases. Any oil which increased in viscosity more than the Lubricant B OE/HDO-10 baseline was suspect due to the insufficient data on cold cranking, starting-and-running, and lubricant pumpability for Army engines,⁽⁶⁾ compounded by a lack of agreement among manufacturers concerning viscosity limits (Figure 4). Since both Lubricant I and Lubricant H increased in viscosity more than the OE/HDO-10 baseline, there is some doubt as to its desirability as a MIL-L-2104C oil.

D. LDT-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Endurance Tests

The data in Tables 15 and 16 show that both test oils Lubricant E and Lubricant G had much less viscosity increase at 40°C and at 100°C than the OE/HDO-30 oil. While this lack of increase is encouraging, the data did not tell how the two test oils performed relative to the OE/HDO-10 oils used at the lower ambient temperatures. Nor did it indicate whether viscosity increases encountered in the test oils would cause cold cranking, starting-and-running, and lubricant pumpability problems in the engines the Army uses. Although limited data exist,⁽⁶⁾ additional information is necessary before any lubricant can be evaluated for its low-temperature properties. The best



* TEMPERATURE LIMITS FOR MIL-L-2104 GRADES 10, 30, 40, AND 50 ARE SPECIFIED IN LUBRICATION ORDERS FOR INDIVIDUAL PIECES OF EQUIPMENT.

FIGURE 4. SURVEY OF RECOMMENDED AMBIENT TEMPERATURE AND LUBRICANT VISCOSITY RANGES

use for the present data is evaluating it against the OE/HDO-30 oil and deciding whether the two test oils are better than the OE/HDO-30 in the applications where the OE/HDO-30 is presently in use.

Examination of the data on this basis shows both test oils performed much better in all categories except in the amount of iron in the oil, as determined by X-ray fluorescence (XRF). Since the measured wear of the critical engine parts (cylinders, rings) was equal for all tests, and all engine parts looked normal regarding wear, perhaps the difference was due to differing oil consumptions or corrosion and wear of engine parts not measured.

The Total Base Number (TBN) for both test oils was less than the OE/HDO-30 baseline oil at the end of the test, indicating less reserve alkalinity remaining to offset the acidic products of combustion. Since the two test oils

both had a lower TBN and a higher iron concentration than the OE/HDO-30 oil, there may be a relation between the two that further investigations could uncover. The sludge and deposit-forming tendency indicators of Pentane B Insolubles, Toluene B Insolubles, Carbon Residue, and Sulfated Ash were much lower for both test oils, as were actual piston and intake valve deposits. The oil consumption was also much lower for both test oils. All these factors averaged together gave an APP of -39 percent for Lubricant E and -29 percent for Lubricant G, indicating that both oils tested were better overall than the OE/HDO-30 acceptable performance level oil in this test.

E. Relationships Between Variables

In this section, the possible relationship between different variables (e.g., oil viscosity or volatility versus wear, and oil basestock or oil additives versus wear or deposits) is explored. The discovery of relationships between variables can hopefully be used to set specifications and specification limits, to reduce test costs, to improve lubricant performance, and to aid in preventive maintenance.

One of the relationships of interest is whether the rate of engine wear can be obtained from examination of properties of the new or used oil. Table 17 lists the variables examined for relations to wear and the resulting curve fits with the "goodness of fit" measure, R^2 , having a value of $R^2 = 0$ for no fit and $R^2 = 1$ for a perfect fit. Note that iron production rate and ring gap increase rate correlate excellently. This means that most of the iron in the lubricant is coming from ring wear, assuming the quantity of iron in the oil agrees with ring weight loss. The iron production rate was obtained by taking the amount of iron in the oil as determined by XRF, accounting for the iron lost in sampling and consumption, and converting this to a rate basis along with the other variables examined. This way comparisons with 240-Hour Tracked-Vehicle Cycle Tests that did not finish the full 240 hours (such as Test 4) are possible, and an indication is given in terms of rate-of-wear/hour that can be compared with other test cycles and test engines for test severity.

TABLE 17. WEAR-RELATED CORRELATIONS BETWEEN VARIABLES FOR THE 6V-53T
ENGINE 240-HOUR TRACKED-VEHICLE CYCLE TESTS

Test Number	Fe Production Rate, mg/hr	Ring Gap Increase rate, in.x10 ⁻⁵ /hr	Liner Scuffing Rate, % Area/hr Thrust Overall	Ring Face Scuff Rate, % Area/hr	Cylinder ID Change rate, in.x10 ⁻⁶ /hr
3	24	1.7	0.10	0.08	5.0
4	102	6.4	0.29	0.27	8.6
5	71	3.8	0.20	0.14	6.3
6	103	5.8	0.19	0.14	6.3
7	42	2.5	0.10	0.09	4.6
8	23	1.3	0.05	0.05	4.6
9	21	1.7	0.06	0.05	0.8

Linear Regression Data Fits With Coefficients of Determination (R^2)

Fe production rate vs. Ring gap increase rate: $Y = -2.8 + 17.5X$, $R^2 = 0.98$

Fe production rate vs. Liner scuffing rate, Thrust: $Y = 0.8 + 384X$, $R^2 = 0.84$

Fe production rate vs. Liner scuffing rate, Overall: $Y = 7.0 + 410X$, $R^2 = 0.74$

Fe production rate vs. Ring face scuffing rate: $Y = 10.0 + 220X$, $R^2 = 0.79$

Fe production rate vs. Cylinder ID change rate: $Y = -7.5 + 12X$, $R^2 = 0.62$

Liner scuffing rate, thrust vs. Ring face scuffing rate: $Y = 0.02 + 0.59X$,
 $R^2 = 0.98$

Ring gap increase rate vs. Ring face scuffing rate: $Y = 0.69 + 13X$, $R^2 = 0.85$

Also showing an excellent correlation is Liner Scuffing Rate versus Ring Face Scuffing Rate, with $R^2 = 0.98$. This correlation indicates that a third quantity is affecting both the liner and the rings in a directly proportional manner, or that the rings or the liner are scuffed, which in turn scuffs the other. Showing less correlation, but nonetheless relatively good fits are iron products versus liner scuffing and Ring Gap Increase Rate versus Ring Face Scuff Rate with $R^2 = 0.84$ and 0.85 , respectively. This correlation is an indication that the predominant wear mechanism is done by scuffing as opposed to smooth, even wear. Since there is a tentative connection between ring/ liner wear and lubricant volatility,⁽⁶⁾ these data suggest that to reduce wear, scuffing is the major area of focus, and lubricant volatility may be the indicator. Lubricant volatility experiments should be performed

in order to test the assertions of Reference 5, and to investigate correlations with oil consumption. The other data fits show some correlation, but not enough for a definite conclusion to be drawn. Other attempted correlations show that there is some linear correlation between ring wear versus kinematic viscosity at 40° or 100°C ($R^2 = 0.61$ and 0.57), or between ring scuffing versus kinematic viscosity at 40° or 100°C ($R^2 = 0.48$ and 0.57). Experiments should be performed to see if viscosities at the temperature encountered on the cylinder walls would correlate better with wear. The lack of volatility data, high-temperature viscosity data, and the limited number of lubricants of varying basestocks make it impossible at this time to discriminate the performance of different lubricants on the basis of lubricant basestock, additives, or interactions between the two.

There is insufficient data to draw significant correlations between variables in either the LD-465-1 engine tests or the LD-465-1C engine tests, each with a total of three tests conducted. The fact that little difference is seen between available test results, besides oil consumption and viscosity increases, also makes any significant analysis difficult.

V. CONCLUSIONS

A. 6V-53T Engine 240-Hour Tracked-Vehicle Cycle Tests

- Cylinder liner wear is not great enough to make distinctions between oils.
- Ring wear is great enough to begin making distinctions between oils.
- Piston WTD deposits and ring groove carbon filling did not vary much between the tested oils.
- A correlation exists between the rate that iron is introduced into the oil and the observed piston ring wear rate. The curve fit for this correlation with $R^2 = 0.98$ is: Fe production rate (mg/hr) = $-2.8 + 17.5$

[Ring Gap Increase Rate (in. $\times 10^{-5}$ /hr)] or Ring Gap Increase Rate = $0.23 + 0.056$ (Fe production rate).

- There is also a direct correlation between cylinder liner scuffing and ring face scuffing. The equation is Linear Scuffing Rate = 0.02 ± 0.59 (Ring Scuffing Rate).
- Overall, the test oils Lubricants E, F, and G performed better than the OE/HDO-30 reference oil and would be satisfactory replacements for OE/HDO-30 in 6V-53T engines. Lubricants C, D, and B performed worse than the OE/HDO-30 oil. Use of the three oils that performed better overall might result in more ring wear with Lubricant E, less with Lubricant F, and equal ring wear with Lubricant G. Use of all three might also result in less scuffing, equal or less deposits, less oil thickening and equal or slightly more oil consumption, except for Lubricant E with less oil consumption. Use of the three oils that performed worse might result in more wear, more scuffing, less deposits, equal or less oil consumption and less oil thickening.
- 240-hr 6V-53T cycle provides lubricant discrimination and is suitable for use in the proposed MIL-L-2104D specification.

B. LD-465-1C Engine 210-Hour Wheeled-Vehicle Cycle Tests

- The viscosities of both test oils Lubricant I and Lubricant H increased more than the OE/HDO-10 baseline oil, and are doubtful as MIL-L-2104 oils until more data on cold cranking, starting-and-running, and lubricant pumpability for Army engines can be obtained.
- Insufficient data exist to make significant correlations between variables.

C. LDT-465-1C 210-Hour Wheeled-Vehicle Cycle Tests

- Overall, the two test oils, Lubricant E and Lubricant G, both performed

better than the OE/HDO-30 baseline and would be satisfactory replacements for applications in LD/LDT-465 engines where the OE/HDO-30 oil is used now. Potential benefits are equal wear, equal or fewer deposits, less oil thickening, and less oil consumption.

- The performance of the two test oils in regards to excessive low-temperature viscosity increases is still unknown due to the lack of data on cold cranking, starting-and-running, and lubricant pumpability for Army engines.
- Lubricant F and Lubricant G appear acceptable as SAE 15W-40 multiviscosity-grade MIL-L-2104 specification oils. Acceptance should be provisional pending the results of work defining low-temperature viscosity limits in Army engines. Although Lubricant E performed acceptably overall, the ring wear seen when using this oil is cause for further investigation.

VI. RECOMMENDATIONS

- A detailed cost-benefit analysis should be performed based on the costs (initial, operational, logistical) of the current MIL-L-2104C oils, and initial screening criteria should be developed to eliminate those candidate lubricants that would not result in an economical solution to the problems they solve.
- Additional testing should be conducted in order to evaluate current and future 10W-X candidate MIL-L-2104 lubricants.
- The effects that current and potential MIL-L-2104 lubricants have on Army combat/tactical engines should be quantified through extensive analysis of field service records, or controlled field tests as necessary to obtain clear results concerning service life at rated power, startability, and fuel and oil consumption rates. In the past, uncontrolled field tests and field service records have yielded ambiguous

figures.⁽⁷⁾ Modifications to past procedures or using controlled field tests may be necessary. The data derived from such tests are necessary to evaluate the discriminatory capabilities of other tests used to evaluate lubricants. Any test used to evaluate lubricant performance should rank oils in the same order as actual service.

- The actual limits of oil viscosity for successful cranking, starting-and-running, and lubricant pumpability should be defined. This could be done by testing Army combat/tactical engines at temperatures ranging from extreme cold to moderate cold.

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APPENDIX A

ENGINE-LUBRICANT COMPATIBILITY TEST #3

240-HOUR TRACKED-VEHICLE CYCLE

USING 6V-53T DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED VEHICLE CYCLE
USING 6V53T DIESEL ENGINE

Test Lubricant: MC-520 (AL-6856-L)
Engine Test Number: CI 5136206-3
Date Completed: 2 February 1979

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

By

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

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6V53T CI5136206-3
BUILD-UP ENGINE MEASUREMENTS

<u>Measurements</u>	<u>INCHES</u> (1)			
	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Specified Limits</u>
Crankshaft main bearing clearance	0.0043	0.0046	0.0044	0.0010-0.0040
Camshaft bearing clearance				
Left Cam	0.0040	0.0055	0.0047	0.0080 max
Right Cam	0.0041	0.0050	0.0045	0.0080 max
Connecting rod bearing clearance	0.0014	0.0026	0.0021	0.0011-0.0041
Crankshaft end-play			0.005	0.004-0.011
Oil pump				
Between rotors			0.003	0.004-0.011
Outer rotor/housing	0.0015	0.0015	0.0015	0.001-0.0035
Cylinder liner block bore				
Taper	0.0000	0.0005	0.0003	0.0015 max
Out-of-round	0.0000	0.0012	0.0007	0.0015 max
Inside diameter	4.3568	4.3580	4.3573	4.3595 max
Cylinder liners (installed)				
Taper	0.0001	0.0009	0.0004	0.002 max (2)
Out-of-round	0.0000	0.0005	0.0001	0.003 max (2)
Inside diameter	3.8750	3.8766	3.8754	3.8752-3.8767
Piston to liner fit	0.0075	0.0095	0.0081	0.0060-0.0095
Piston diameter	3.8653	3.8675	3.8666	3.8669-3.8691
Fire ring				
End gap	0.026	0.034	0.030	0.020-0.046
Side clearance	0.002	0.003	0.003	0.003-0.006
#1 Compression ring				
End gap	0.025	0.030	0.029	0.020-0.046
Side clearance	0.008	0.009	0.008	0.007-0.010
#2 & #3 Compression rings				
End gap	0.025	0.034	0.028	0.020-0.046
Side clearance	0.006	0.007	0.006	0.005-0.008
Oil rings				
End gap	0.018	0.023	0.020	0.010-0.025
Side clearance	0.002	0.003	0.002	0.0015-0.0055

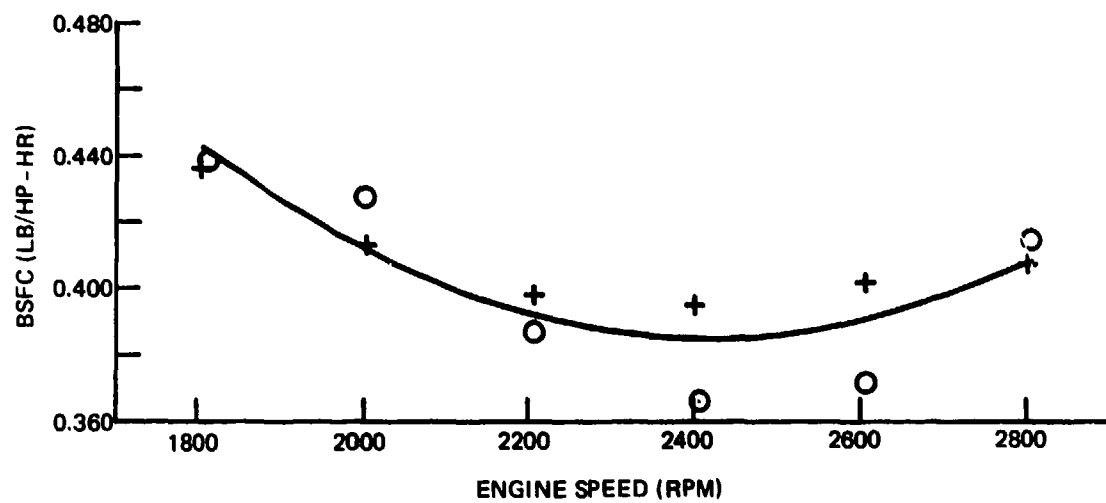
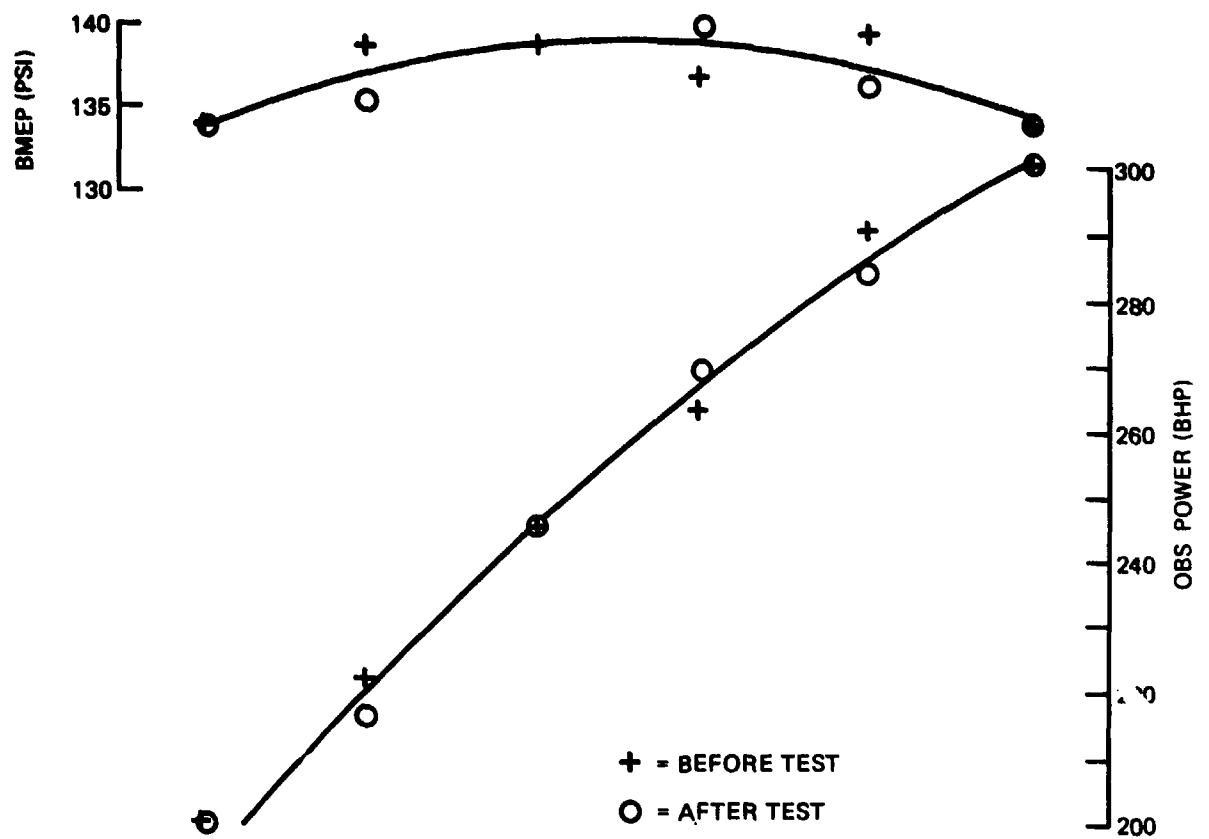
(1) Limits on new parts unless maximum wear limit specified.

(2) Wear limits with new liners in a used block.

6V53T FULL LOAD PERFORMANCE

TEST NO.: CI5136208-3

OIL: AL-6856-L



**6V53T ENDURANCE TEST
SUMMARY OF OPERATING DATA**

TEST NO.: CI 5136206-3

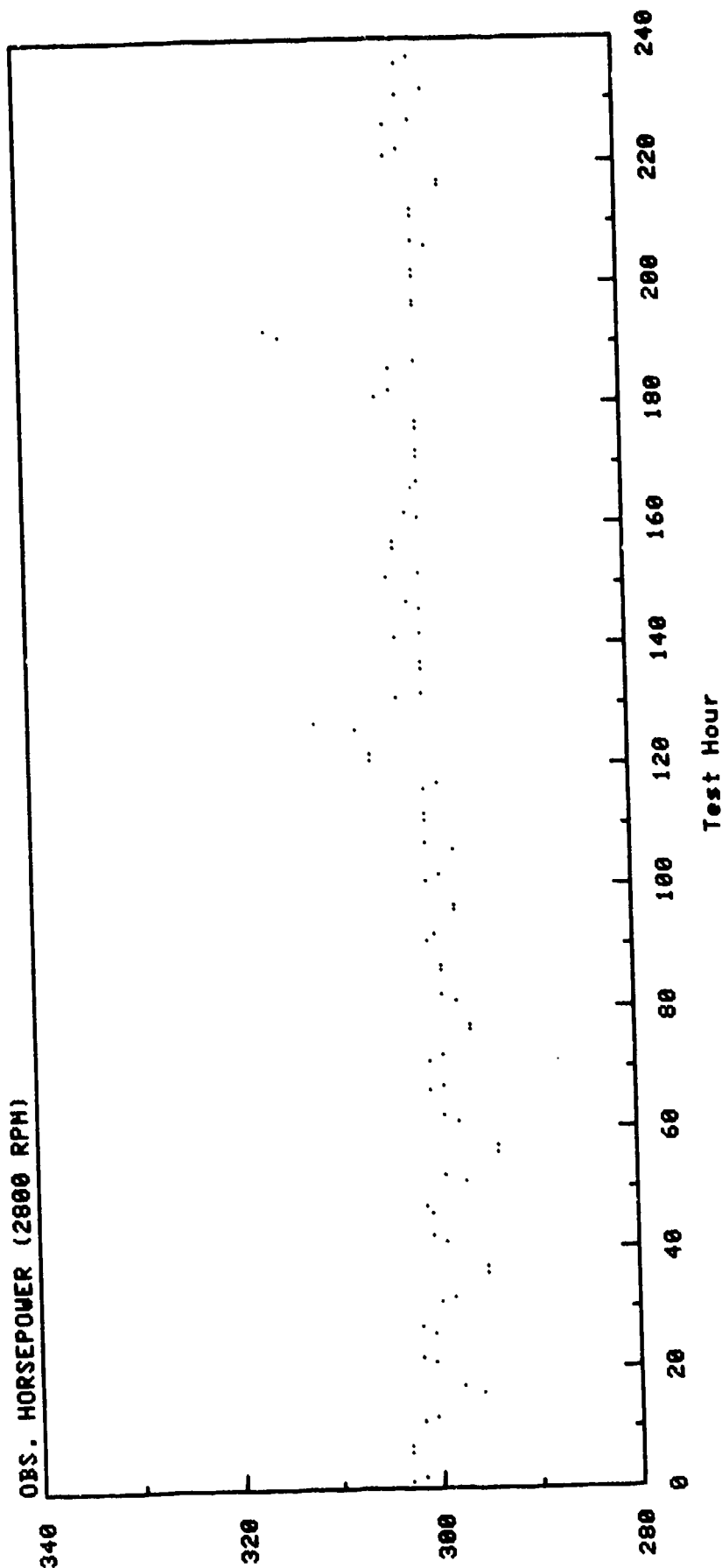
OIL: AL-6856-L

	2200 RPM			2800 RPM		
	<u>Avg</u>	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Engine Speed, rpm	2204	2198	2210	2807	2798	2818
Load, lb	462	445	469	438	433	469
Obs. Power, bhp	248	239	253	300	296	322
Fuel Rate, lb/hr	97.2	96.1	98.2	120.7	119.6	121.8
BSFC, lb/bhp-hr	0.392	0.388	0.402	0.402	0.378	0.404
<u>Temperatures, °F</u>						
Jacket In	145	127	155	136	125	145
Jacket Out	158	150	165	152	149	158
Oil Sump	247	245	249	250	248	250
Inlet Air (Compressor)	73	52	83	76	52	86
Airbox	226	239	203	273	244	293
Exhaust before Turbo	985	930	1010	1012	950	1040
Exhaust after Turbo	774	370	870	726	450	890
Fuel at Filter	85	99	62	91	78	99
<u>Pressures, psig</u>						
Compressor Discharge	8.5	8.4	9.0	12.0	11.6	12.7
Blower Discharge	10.7	10.4	11.4	18.0	17.4	19.0
Exhaust Before Turbo	8.3	8.2	8.7	12.5	12.2	12.7
Oil Consumption (lb/hr avg for 240 hr)	0.646					

6V53T ENDURANCE TEST - 240 HR. TRACKED

Test No. C15136206-3 Oil: AL-6856-L

OBS. HORSEPOWER (2800 RPM)



6V53T ENDURANCE TEST - 240 HR. TRACKED

Test No. CI5136206-3 Oil: AL-6856-L

BSFC (2800 rpm)

0.440

0.420

0.400

0.380

0.360

0.340

0

20

40

60

80

100

120

140

160

180

200

220

240

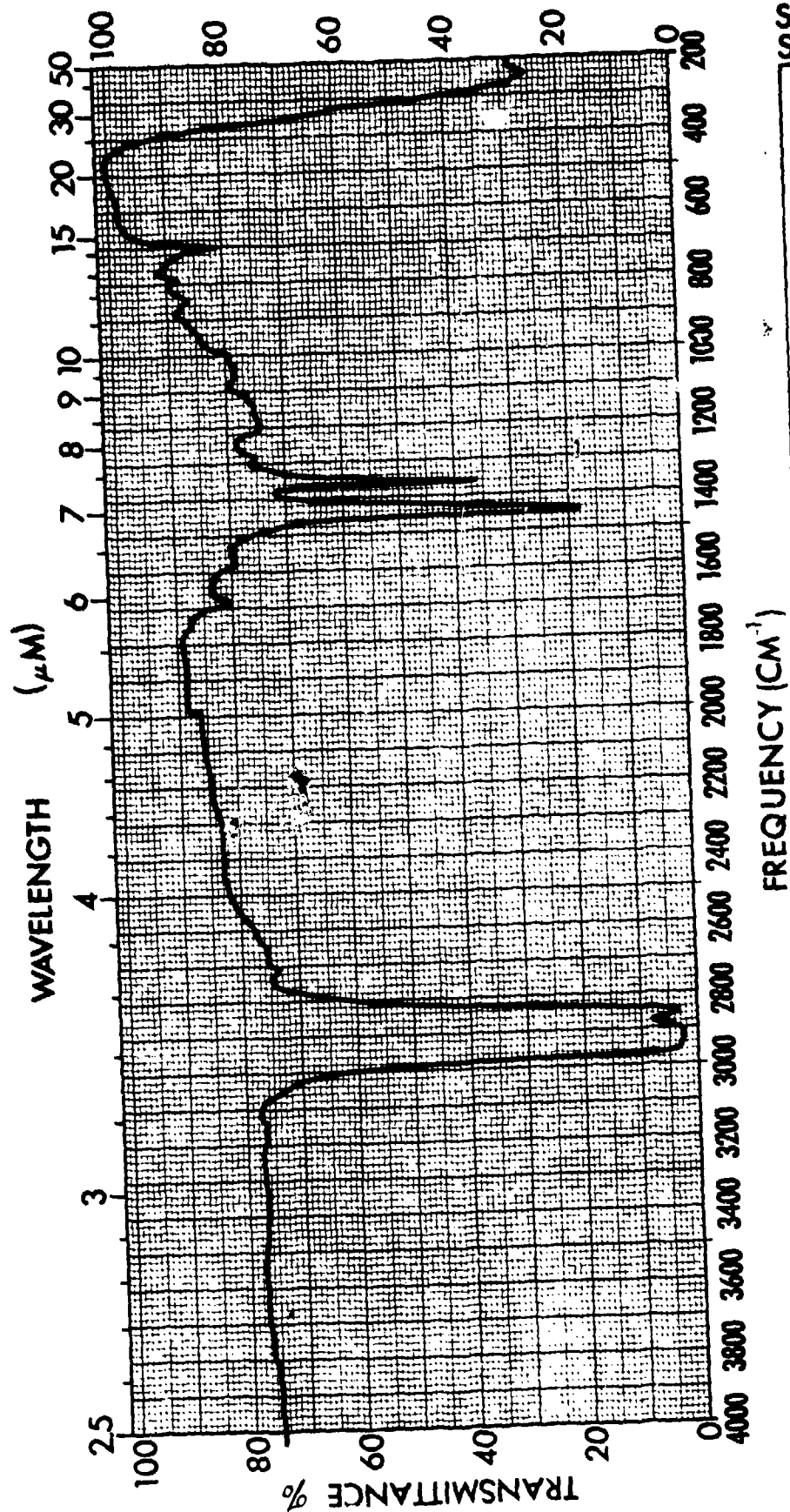
Test Hour

A-8

LUBRICANT ANALYSIS
6V53T - C15136206-3
LUBRICANT: AL-6856-L
FUEL: 1-H CAT

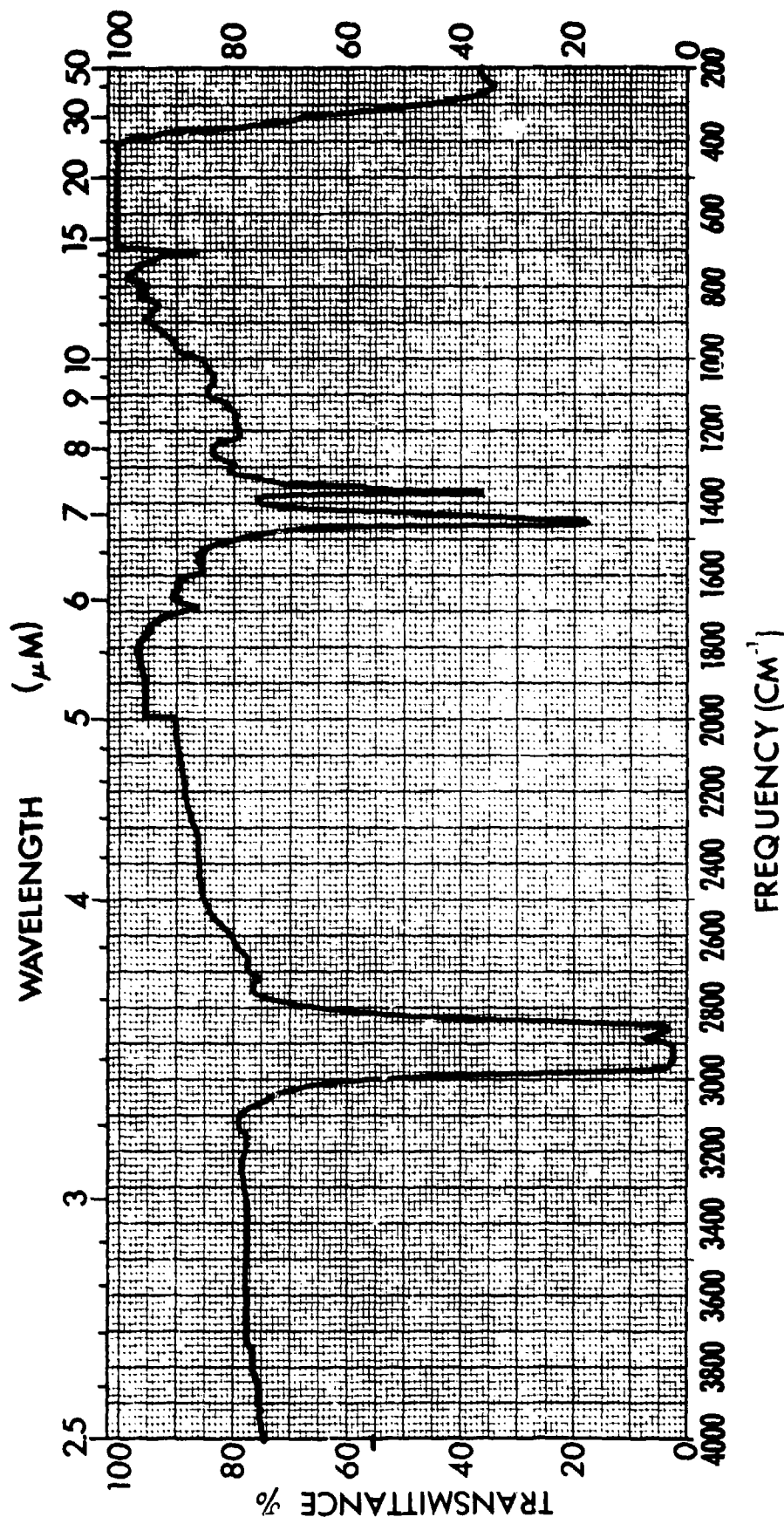
Property	ASTM Method	TEST HOUR												
		New	20	40	60	80	100	120	140	160	180	200	220	240
K. Vis @40°C, cSt	D 445	106.7	127.0	139.8	148.5	153.0	154.5	155.4	128.9	136.3	142.6	146.3	149.2	149.6
K. Vis @100°C, cSt	D 445	11.65	11.91	12.70	13.06	13.43	13.66	13.69	12.09	12.40	12.78	13.08	13.26	13.39
VI	D 2270	96	78	79	77	78	81	80	80	77	77	79	79	81
TAN	D 664	2.3	2.56	2.65	2.76	3.24	3.21	3.52	2.83	3.09	3.09	3.73	3.63	3.53
TBN	D 2896	13.9	12.00	11.26	11.75	11.75	11.75	12.98	11.26	11.51	11.51	12.00	11.51	12.00
Insolubles, %	D 893													
Pentane A		0.04	0.05	0.08	0.06	0.09	0.08	0.08	0.07	0.08	0.10	0.08	0.09	0.07
Benzene A		0.04	0.08	0.09	0.05	0.09	0.08	0.05	0.06	0.07	0.07	0.06	0.06	0.05
Pentane B		0.03	0.07	0.12	0.11	0.66	0.93	0.97	0.08	0.26	0.33	0.49	0.87	1.14
Benzene B		0.01	0.08	0.10	0.12	0.56	0.75	0.64	0.08	0.18	0.21	0.34	0.70	0.88
Flash Point, °C	D 92	223	-	-	-	-	-	236	-	-	-	-	-	240
Carbon Residue, %	D 524	2.1	-	-	-	-	-	3.12	-	-	-	-	-	3.32
Sulfated Ash, %	D 872	1.6	-	-	-	-	-	2.04	-	-	-	-	-	2.01
Gravity, °API	D 287	25.5	-	-	-	-	-	23.8	-	-	-	-	-	23.3
Wear Metals by XRF														
Fe, ppm			31	45	53	63	65	74	30	40	56	60	65	88
No others detected														

- = Not determined



SPECTRUM NO. 1632
 SAMPLE AL-6856-L 120 HR

SPECTRUM NO. 1632	ORIGIN	LEGEND	REMARKS
SAMPLE AL-6856-L		1.	
120 HR	PURITY	2.	
	PHASE	DATE 2/13/79	
	THICKNESS 0.015	OPERATOR	

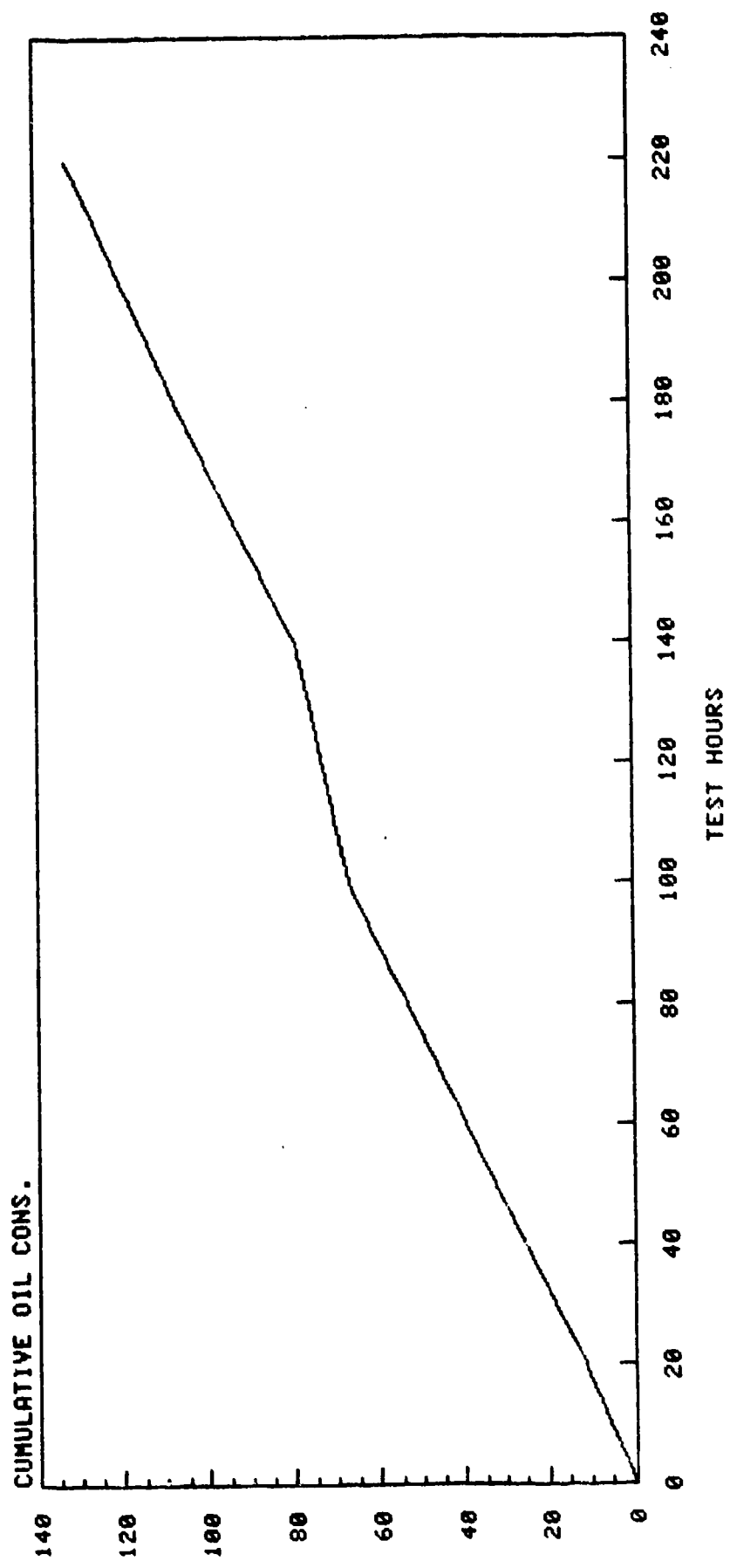


SPECTRUM NO. 1633
 SAMPLE AL-6856 240 HR

SPECTRUM NO.	ORIGIN	LEGEND	REMARKS
1633		1.	
SAMPLE AL-6856-L		2.	
240 HR	PURITY	DATE 2/13/79	
	PHASE	OPERATOR DDD	
	THICKNESS 0.015		

6V53T ENDURANCE TEST -CUM. OIL CONS.

Test No. C15136206-3 OIL:AL-6855-L



ENGINE NO. CI 5136206-3

OIL: AL-6856-L

TEST HOURS: 240

Cylinder No.	Cylinder Liner ID					
	Perpendicular to Crankshaft			Parallel to Crankshaft		
	Top	Middle	Bottom	Top	Middle	Bottom
1L Before	3.8751	3.8750	3.8753	3.8752	3.8755	3.8758
After	3.8764	3.8762	3.8763	3.8759	3.8760	3.8765
Change	0.0013	0.0012	0.0010	0.0007	0.0005	0.0007
2L Before	3.8752	3.8754	3.8758	3.8750	3.8755	3.8758
After	3.8763	3.8770	3.8769	3.8760	3.8761	3.8759
Change	0.0011	0.0016	0.0011	0.0010	0.0006	0.0001
3L Before	3.8757	3.8762	3.8766	3.8757	3.8762	3.8764
After	3.8768	3.8770	3.8771	3.8768	3.8770	3.8771
Change	0.0011	0.0008	0.0005	0.0011	0.0008	0.0007
1R Before	3.8750	3.8751	3.8753	3.8750	3.8750	3.8752
After	3.8768	3.8771	3.8770	3.8766	3.8765	3.8768
Change	0.0018	0.0020	0.0017	0.0016	0.0015	0.0016
2R Before	3.8750	3.8750	3.8751	3.8750	3.8750	3.8752
After	3.8765	3.8764	3.8764	3.8759	3.8758	3.8761
Change	0.0015	0.0014	0.0013	0.0009	0.0008	0.0009
3R Before	3.8750	3.8751	3.8752	3.8750	3.8751	3.8753
After	3.8768	3.8771	3.8770	3.8761	3.8761	3.8766
Change	0.0018	0.0020	0.0018	0.0011	0.0010	0.0013

ENGINE NUMBER CI5136206-3

OIL: AL-6856-L

TEST HOURS: 240

Piston No.	Piston Ring Gap, Inches						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
1L Before	0.026	0.030	0.030	0.028	0.021	0.018	0.018
After	0.029	0.031	0.031	0.030	0.027	0.025	0.025
Change	0.003	0.001	0.001	0.002	0.006	0.007	0.007
2L Before	0.034	0.028	0.028	0.029	0.023	0.019	0.019
After	0.035	0.027	0.029	0.029	0.028	0.025	0.024
Change	0.001	0.001	0.001	0.000	0.005	0.006	0.005
3L Before	0.029	0.030	0.030	0.028	0.022	0.018	0.019
After	0.035	0.031	0.034	0.029	0.028	0.025	0.024
Change	0.006	0.001	0.004	0.001	0.006	0.007	0.005
1R Before	0.031	0.030	0.025	0.031	0.020	0.020	0.020
After	0.034	stuck	0.025	0.031	0.028	0.025	0.024
Change	0.003	-	0.000	0.000	0.008	0.005	0.004
2R Before	0.032	0.028	0.027	0.027	0.021	0.019	0.018
After	0.034	0.028	0.026	0.027	0.026	0.025	0.024
Change	0.002	0.000	-0.001	0.000	0.005	0.006	0.006
3R Before	0.027	0.025	0.023	0.024	0.021	0.019	0.018
After	0.029	0.034	0.022	0.025	0.028	Collapsed	0.025
Change	0.002	0.009	-0.001	0.001	0.007	-	0.007

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked PISTON NO. 1 Right
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-6856-L
 RATER E. Lyons DATE 2-5-79
 LABORATORY TEST NUMBER C15136206-3
 STAND NO. 5 ENGINE NO. 5136206
 FUEL 1-H CAT

NO. 1 GROOVE, VOLUME-%	384.01
PISTON WTD* RATING	

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				UNDER-CROWN	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	AREA-%	DEMERIT
CARBON	HC 1.00			70	70.00	85	85.00	40	40.00		
	MHC 0.75			30	22.50			60	30.00		
	MC 0.50										
	LC 0.25										
	VLC 0.15	100	15.00			15	2.25	10	1.50	25	3.75
CARBON RATING		15.00		92.50		87.50	91.50	70.00	3.75		
LACQUER	BL 0.100				80	8.00			50	5.00	
	DBrL 0.075								25	1.875	7.50
	AL 0.050										
	LAL 0.025										
	VLAL 0.010										
LACQUER RATING					9.50				6.875	7.50	
CLEAN	0										
ZONAL RATING											
LOCATION FACTOR											
WEIGHTED RATING	15.00	0	92.50	9.50	87.50	91.50	70.00	10.625	7.50		

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 240
 TEST LABORATORY AFLRL
 LUBRICANT AL-6856-L

RATER E. Lyons DATE 2-5-79
 LABORATORY TEST NUMBER CI5136206-3
 STAND NO. 5 ENGINE NO. 5136206
 FUEL 1-H CAT

PISTON NO. 2 Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES										LANDS				UNDER-CROWN	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4	
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC 1.00			70	70.00					85	85.00	60	60.00				
	MHC 0.75	5	3.75	30	22.50									50	25.00		
	MC 0.50	70	35.00			10	2.50			15	3.75						
	LC 0.25					90	13.50					40	6.00	25	3.75	80	12.00
	VLC 0.15	25	3.75														
CARBON RATING		42.50		92.50		16.00				88.75		66.00		28.75		12.00	
LACQUER	BL 0.100							100	10.00					25	2.50	5	5.00
	DBrL 0.075																100 7.50
	AL 0.050															15	0.75
	LAL 0.025																
	VLAL 0.010																
LACQUER RATING														2.50		5.75	7.50
CLEAN 0																	
ZONAL RATING																	
LOCATION FACTOR										88.75						17.75	
WEIGHTED RATING		42.50		92.50		16.00		10.00				66.00		31.25			7.50

*WEIGHTED TOTAL DEPOSITS

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 3 Right

RATER E. Lyons DATE 2-5-79
LABORATORY TEST NUMBER CI5136206-3
STAND NO. 5 ENGINE NO. 5136206
FUEL J-H CAT _____

TEST PROCEDURE _____ Tracked
TEST HOURS 240 _____
TEST LABORATORY AFRL _____
LUBRICANT AL-6856-I _____

BATES E. LYONS DATE 2-5-79

LABORATORY TEST NUMBER CI5136206-3

LABORATORY TEST NUMBER: 5136206
STAND NO 5 ENGINE NO

SI AND NO. _____ ENGINE NO. _____
TYPE: J-H CAT

FUEL J-H CAT

[illegible]

WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 240
 TEST LABORATORY AFLRL
 LUBRICANT AL-6856-I

RATER E. Lyons DATE 2-5-79
 LABORATORY TEST NUMBER CI5136206-3
 STAND NO. 5136206
 FUEL 1-H CAT

PISTON NO. 1 Left

LUBRICANT AL-6856-I															FUEL 1-H CAT															NO. 1 GROOVE, VOLUME-%																													
																														PISTON WTD* RATING															359.0														
DEPOSIT TYPE		DEPOSIT FACTOR		GROOVES										LANDS										UNDER-CROWN																																			
				NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4																																									
CARBON		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT																																
HC		100		100	100.0																																																						
MHC																																																											
MC																																																											
LC		100	25.00																																																								
VLC																																																											
CARBON RATING		25.00		100.00																																																							
BL																																																											
DBrL								100	10.00																																																		
AL																																																											
LAL														100	5.00																																												
VLAL																																																											
RL																																																											
LACQUER RATING																																																											
CLEAN																																																											
ZONAL RATING																																																											
LOCATION FACTOR																																																											
WEIGHTED RATING		25.00		100.00		10.00																																																					

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 240
 TEST LABORATORY AFLRL
 LUBRICANT AL-6856-L

RATER E. Lyons DATE 2-5-79
 LABORATORY TEST NUMBER CI513606-3
 STAND NO. 5 ENGINE NO. 5136206
 FUEL 1-H CAT

PISTON NO. 2 Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC	1.00	100	100.00		90	90.00	80	80.00										
	MHC	0.75																	
	MC	0.50																	
	LC	0.25	100	25.00						70	17.50								
	VLC	0.15				10	1.50	20	3.00	20	3.00	70	10.50						
CARBON RATING		25.00	100.00			91.50	83.00	20.50	10.50										
LACQUER	BL	0.100				100	10.00	50	5.00			10	10.00	15	1.50				
	DBrL	0.075						50	3.75					15	1.125	100	7.50		
	AL	0.050																	
	LAL	0.025																	
	VLAL	0.010																	
LACQUER RATING																			
CLEAN		0																	
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		25.00	100.00	10.00	8.75	91.50	83.00	30.50	13.125										
*WEIGHTED TOTAL DEPOSITS																			

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-6856-L

RATER E. Lyons DATE 2-5-79
 LABORATORY TEST NUMBER CI5136206-3
 STAND NO. 5 ENGINE NO. 5136206
 FUEL 1-H CAT

PISTON NO. 3 Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1 GROOVE, VOLUME-%	PISTON WTD* RATING
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC 1.00			10	10.00					20	20.00	80	80.00						
	MHC 0.75			90	67.50														
	MC 0.50	45	22.50																
	LC 0.25	55	13.75			25	6.25							70	17.50				
	VLC 0.15					75	11.25			80	12.00	20	3.00	15	2.25	75	11.25		
CARBON RATING		36.25		77.50		17.50				32.00		83.00		19.75		11.25			
LACQUER	BL 0.100							100	10.00					15	1.50				
	DBrL 0.075																	100	7.50
	AL 0.050															25	1.25		
	LAL 0.025																		
	VLAL 0.010																		
LACQUER RATING														1.50		1.25		7.50	
CLEAN 0																			
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		36.25		77.50		17.50		10.00		32.00		83.00		21.25		12.50		7.50	

*WEIGHTED TOTAL DEPOSITS

RATING DATA SHEET

Test Run at AFLRL
 Test Oil: AL-6856-L
 Test No. CI 5136206-3
 Test Stand: 5
 Engine No.: 5136206
 Test Fuel: 1-H CAT
 Date Started: 14 January 1979
 Date Completed: 2 February 1979
 Test Hours: 240

A. Cylinder Liner Ratings

Intake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
1 L	1
2 L	2
3 L	5
1 R	3
2 R	10
3 R	5
Average	4.0

Scuffing, Glazing and Lacquer*

<u>Cylinder No.</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>Total</u>		
1 L	5	10	7	20	80
2 L	15	10	12	30	70
3 L	10	10	10	15	85
1 R	20	10	15	10	90
2 R	75	25	50	30	70
3 R	10	10	10	20	80
Average	22.5	12.5	17.0	21.0	79

* Ring Travel Area

RATING DATA SHEET - CONTINUED

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition				y=ring face chipped ●-rings removed
	Fire	No.1	No.2	No.3	
1 L	F 40%	F 1%	F 5%	F	
2 L	●57.C.5 30%	F 5%	F 7%	F 10%B	
3 L	yF 60B	F 15B	F 30B	F 35B	
1 R	yF 75B	+F 100B	F 70B	F 35B	
2 R	F 15B	F 20B	F 50B	F 70B	
3 R	*●40% C.S. 40B	F 50B	F 5B	F 15B	

+ Ring collapsed, not removed

* Face has two small chipped places

Cylinder No.	Ring Groove Carbon Filling and Oil Groove Lacquer				Oil Groove Lacquer	
	Fire	No.1	No.2	No.3	Upper	Lower
1 L	10	90	0	0	3.0	3.0
2 L	5	90	5	0	3.0	3.0
3 L	5	85	15	0	3.0	3.0
1 R	5	+	85	0	3.0	3.0
2 R	10	75	15	0	3.0	3.0
3 R	10	95	15	0	3.0	3.0

+ Ring collapsed, not removed

Land Description

Cylinder No.	Description
1 L	Normal H. C.
2 L	Normal H. C.
3 L	Normal H. C.
1 R	Normal H. C.
2 R	Normal H. C.
3 R	Normal H. C.

Cylinder No.	Skirt	
	Thrust	Anti-Thrust
1 L	5.0 Light Scratches	5.2 Light Scratches
2 L	5.0 Plate Melt 20% Scratches	5.5 Light Scratches
3 L	5.4 Scuff 10% Scratches	5.4 Scuff 5% Scratches
1 R	5.3 Platemelt 5%, Scuff 10%	5.3 Scuff 5% Scratches
2 R	5.6 Platemelt 15%, Scuff 30%	5.5 Scuff 5% Scratches
3 R	5.6 Platemelt 5% Scratches	5.3 Light Scratches

RATING DATA SHEET - CONTINUED

C. Other Ratings

Combustion Chambers

<u>Cylinder No.</u>	<u>Description</u>	<u>Cylinder No.</u>	<u>Description</u>
1 L	20% BHC 70 AHC 10% Soot	1 R	20% AHC 80% Soot
2 L	10% CHC 90 AHC	2 R	10% CHC 20% BHC 70% AHC
3 L	10 BHC 70 AHC	3 R	5% DHC 10 BHC 85 AHC

Valve Covers, Oil Pan and Cylinder Head Deck

Covers	Clean
Pan	Clean
Deck	Clean

D. Interim Inspections

Inspection

120 Hour

1 L	Normal
2 L	Normal
3 L	Normal
1 R	2nd comp ring blackened, heavy glaze, ports normal
2 R	Normal
3 R	Heavy Lacquer on skirt, fire ring blackened

180 Hour

1 L	Normal
2 L	Normal
3 L	Normal
1 R	No. 2 comp ring black, same as 120 hour
2 R	Normal
3 R	Same as 120 hour

RING STICKING

Test No. CI-3

Engine Model 6V53T-CI Serial No. CI 5136206-3 Date 2-5-79
 Fuel 1-H CAT Lubricant AL-6856-L Observer E. Lyons

Ring No.	Piston Number					
	1L	2L	3L	1R	2R	3R
1	F	5% P	F	F	F	40%P
2	F	F	F	Collapsed F	F	F
3	F	F	F	F	F	F
4	F	F	F	F	F	F

Indicate by letter — Free or Sluggish, or by number and letter — percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

PISTON GROOVE INSIDE DIAMETER - % RING SUPPORTING CARBON

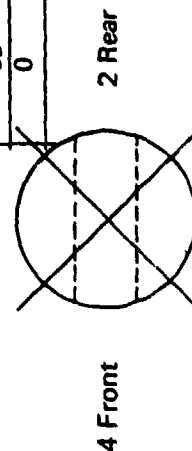
Test No. CI-3

Engine Model 6V53T-CI Serial No. CI513206-3 Date 2-5-79
 Fuel 1-H CAT Lubricant AL-6856-L Observer E. Lyons

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	10	0	0	RING REMOVED		
	2	50	80	0	RING REMOVED		
	3	95	10	0	RING REMOVED		
	4	40	100	40	RING REMOVED		

3rd Groove

1 Thrust Side	100
	100
	85
	0



PISTON SURFACE CONDITION

Test No. CI-3

Engine Model 6V53T-CI Serial No. CI 5135206-3 Date 2-5-79
 Fuel 1-H CAT Lubricant AL-6856-F Observer E. Lyons

	Piston Number					
	1L	2L	3L	1R	2R	3R
Top Land	N	N	N	N	N	N
Skirt						
Piston Pin	N	N	N	N	N	N

Pages 1 through 2 and 59 through 65 of Manual.

VALVE DEPOSITS

Test No. CI-3

Engine Model 6V53T-CI Serial No CI5136206-3 Date 2-5-79
 Fuel 1-H CAT Lubricant AL-6856-L Observer E. Lyons

Cylinder Number													
	1L		2L		3L		1H		2R		3R		
	INT	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Head*	EXH	HEAVY	CARBON	RUILD	UP	C	T	A	H. C.				
Face	INT	100Z#9	LACQ	TO	LIGHT	CARBON							
	EXH												
Tulipt	INT	100Z#9	LACQ	TO	HEAVY	CARBON							
	EXH												
Stem	INT	100Z#9	LACQ	TO	CLEAN								
	EXH												

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S, (Page 5).

Lacquer: Pages 4, 36 and 37.

EXHAUST VALVE SURFACE CONDITIONS

Engine Model 6V53T -CI Test No. CI-3 Date 2-5-79
 Serial No. CI5136206-3
 Fuel 1-H CAT Lubricant AL-6856-L Observer E. Lyons

	1L	2L	3L	1R	2R	3R
Freedom in Guide	F	F	F	F	F	F
Head	N	N	N	N	N	N
Face	SOME LIGHT PITTING AND LEAKING					
Seat	N	N	N	N	N	N
Stem	N	N	N	N	N	N
Tip	N	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

TAPPETS, CAMS, AND ROCKER ARMS

Test No. CI-3

Engine Model 6V53T-CI Serial No. CI5136206-3 Date 2-5-79
 Fuel I-H CAT Lubricant AL-6856-L Observer E. Lyons

		Cylinder Number					
		1L	2L	3L	1R	2R	3R
Tappet Deposit	INT						
	EXH						
	INJ						
Tappet Surface Condition	INT	N	O	R	M	A	L
	EXH						
Cam Lobes			"				
Rocker Arms	Tip	INT					
		EXH					
	Bushing	INT					
		EXH					
	Shaft	INT					
		EXH					

Lacquer: Pages 4, 36 and 37 of Manual.
 See Pages 1, 2, 16 through 23, and 54 through 65.

SURFACE CONDITION

Engine Model 6V53T-CI Test No. CI-3 Date 2-5-79
 Serial No. CI 5136206-3
 Fuel I-H CAT Lubricant AL-6856-L Observer E. Lyons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing	N			R	M	A	L
-Journal				"			
Rod-Bearing				"			
-Journal				"			
Piston Pin				"			
Bushing				"			

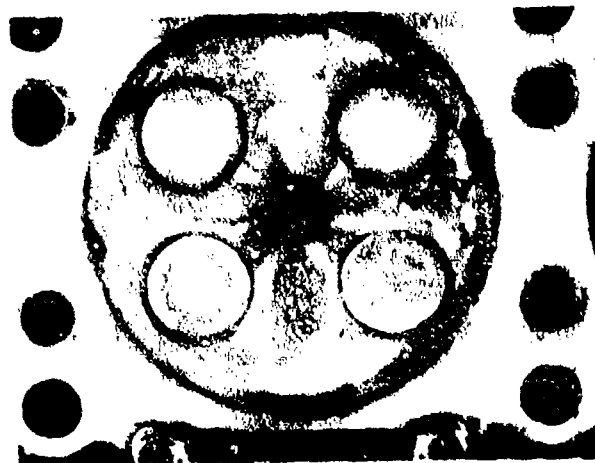
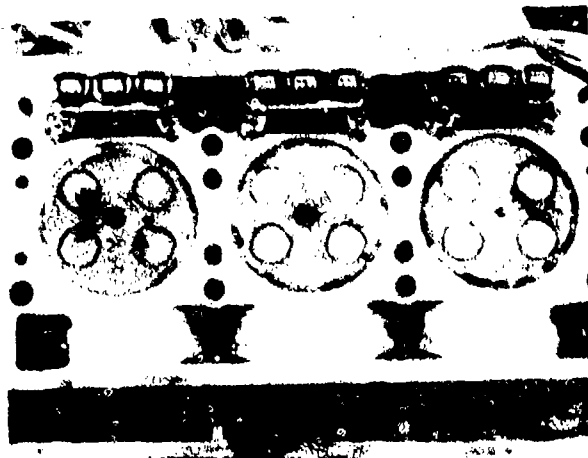
Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST NO.: C15136206-3

OIL: AL-8858-L



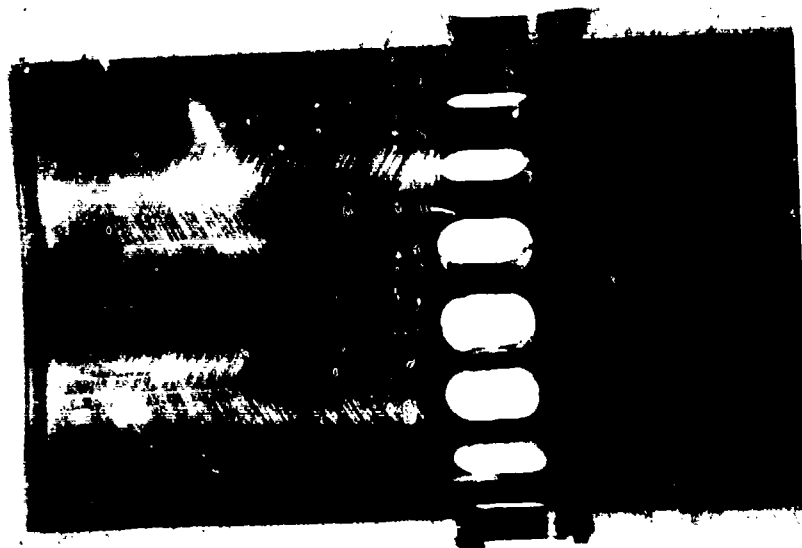
REPRESENTATIVE CYLINDER (2 LEFT)

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



3-LEFT ANTI-THRUST

CONDITION OF PISTON RING FACE

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



1 RIGHT



2 RIGHT



3 RIGHT

CONDITION OF PISTON RING FACE

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



1 LEFT



2 LEFT



3 LEFT

CONDITION OF PISTON AND CYLINDER LINER

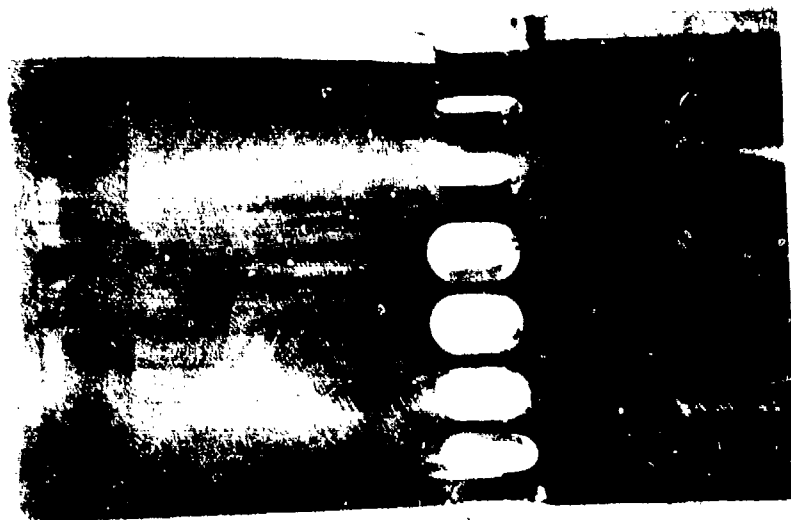
TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



1-RIGHT THRUST

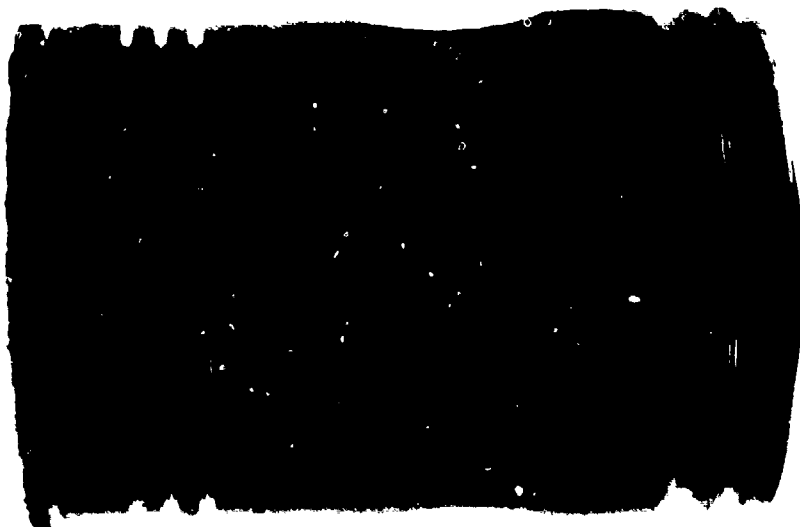


CONDITION OF PISTON AND CYLINDER LINER

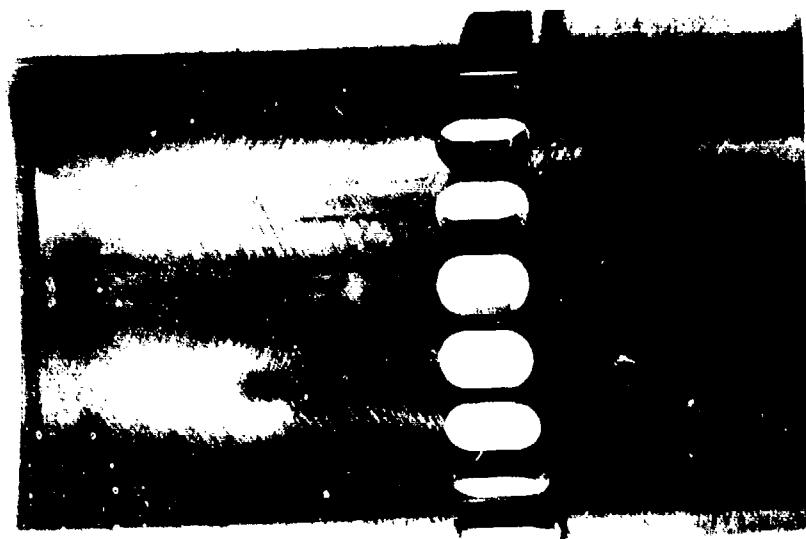
TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



1-LEFT THRUST



CONDITION OF PISTON AND CYLINDER LINER

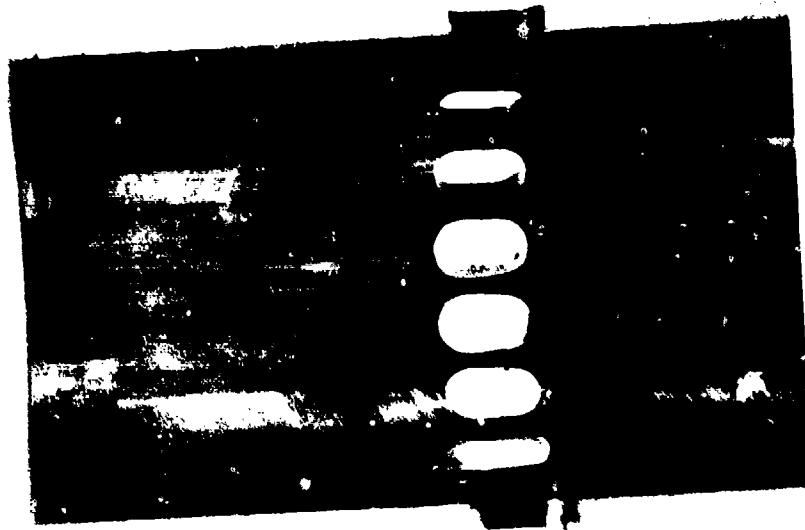
TEST TIME: 240 HOURS

TEST NO.: CI5136206

OIL: AL-6856-L



2-RIGHT THRUST

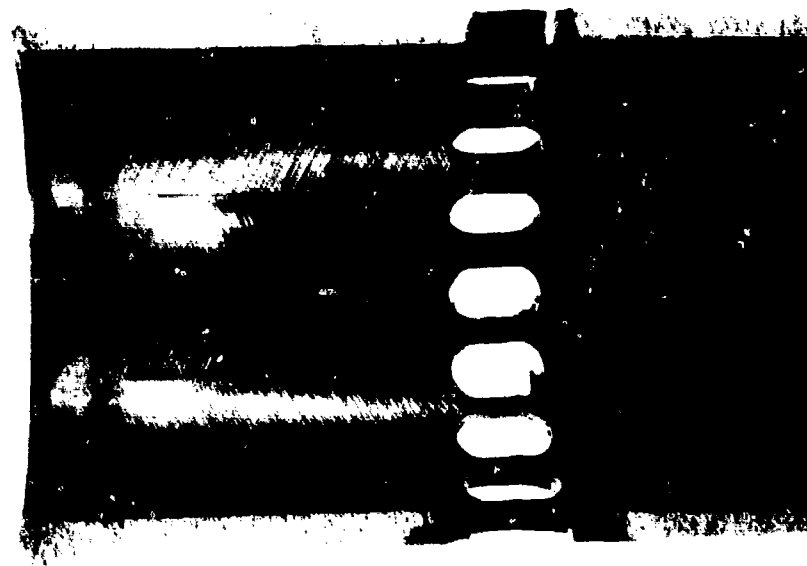


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



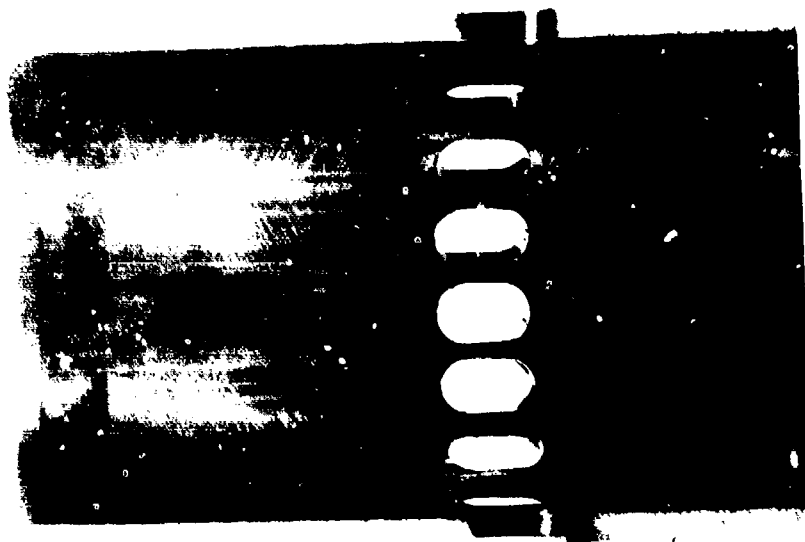
2-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



3--RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

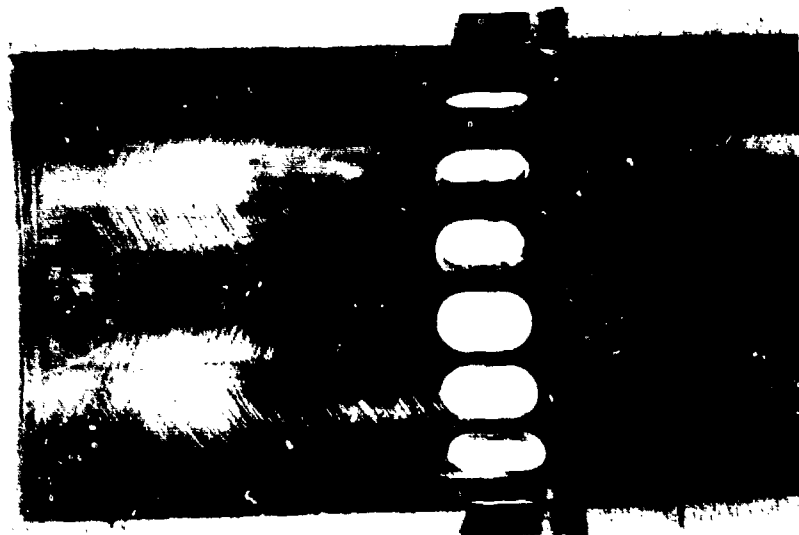
TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



3-LEFT THRUST

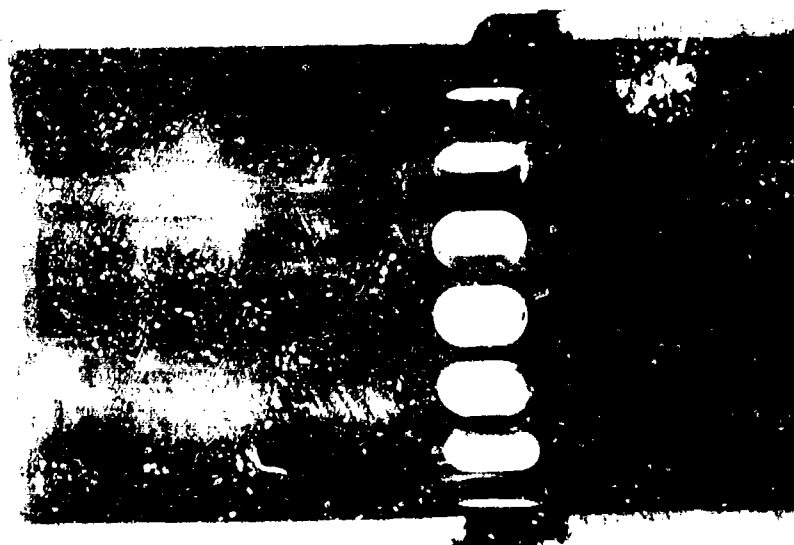


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



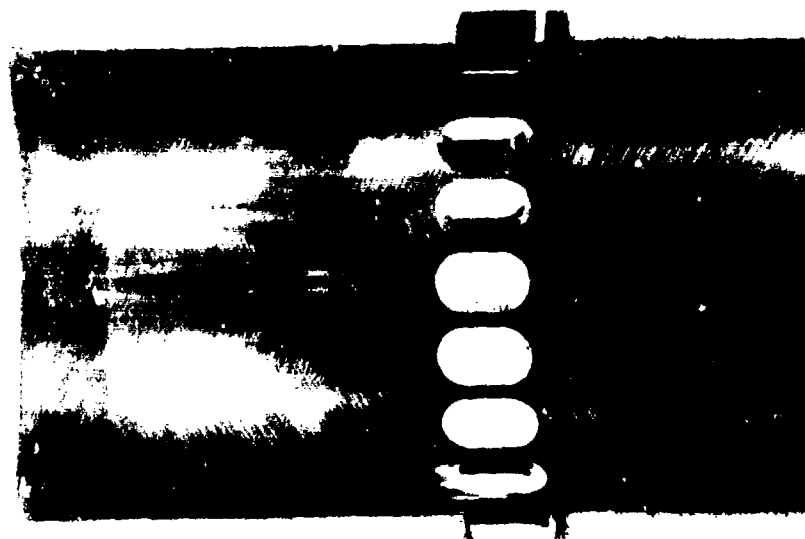
1-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



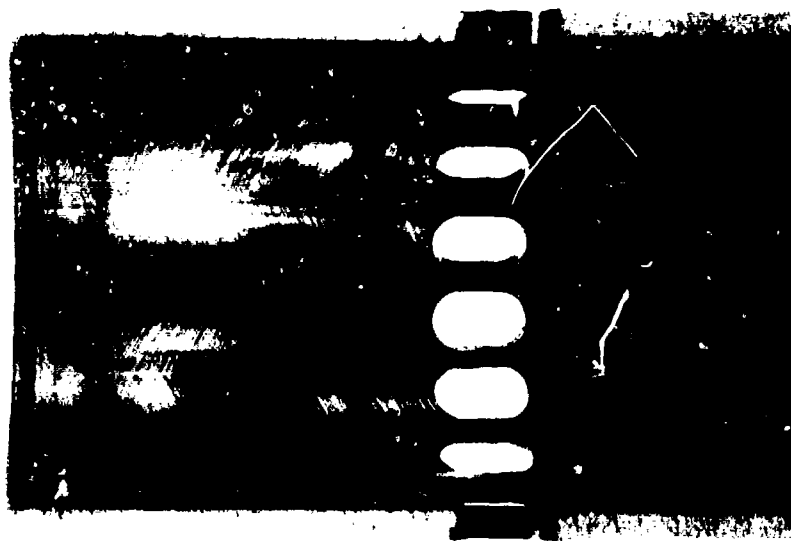
1-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6956-L



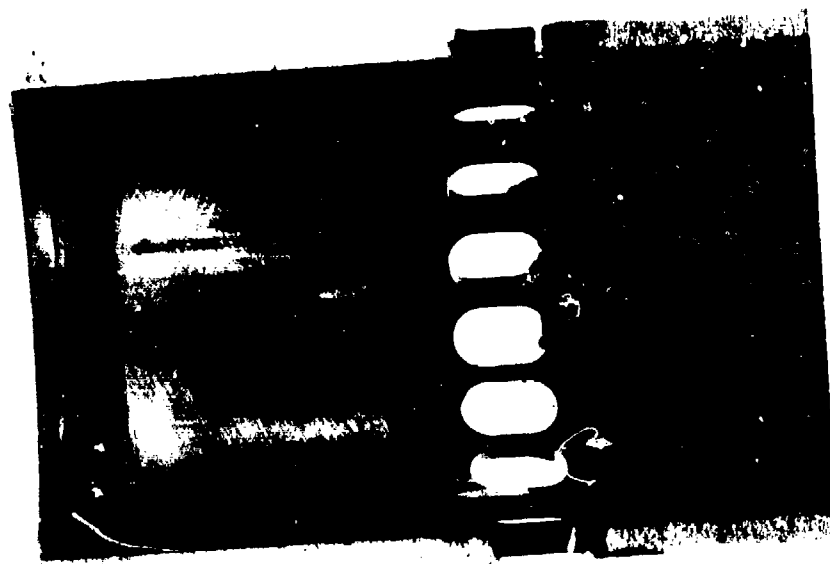
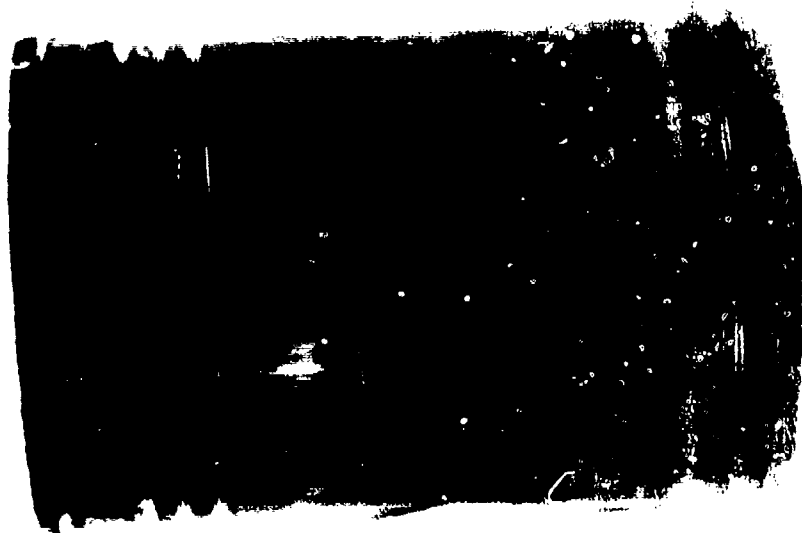
2-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-3

OIL: AL-6856-L



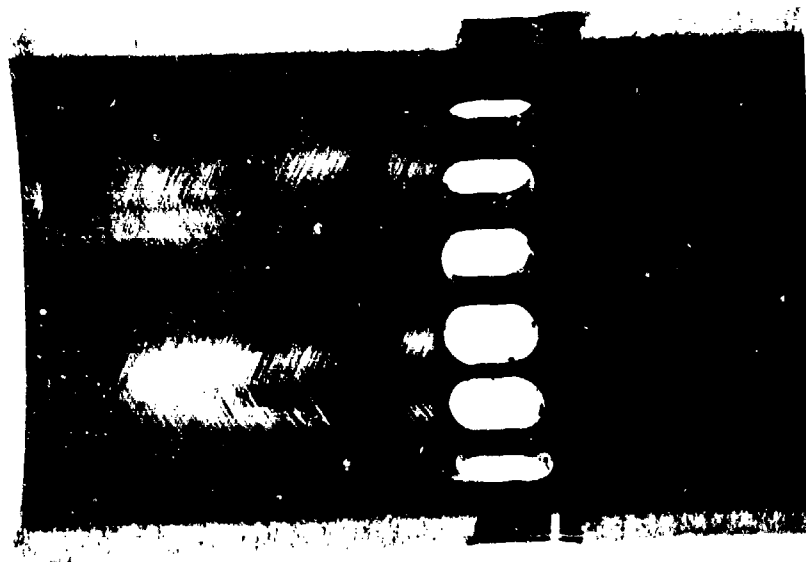
2-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: C15136206-3

C L: AL-8256-L



3-RIGHT ANTI-THRUST

APPENDIX B
ENGINE-LUBRICANT COMPATIBILITY TEST #4
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V53T DIESEL ENGINE

Test Lubricant: MC-606 (AL-6855-L)
Engine Test Number: CI5136206-4
Date Completed: 27 February 1979

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Petroleum and Materials Department

by

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V53T
BUILD-UP ENGINE MEASUREMENTS
CI 5136206-4

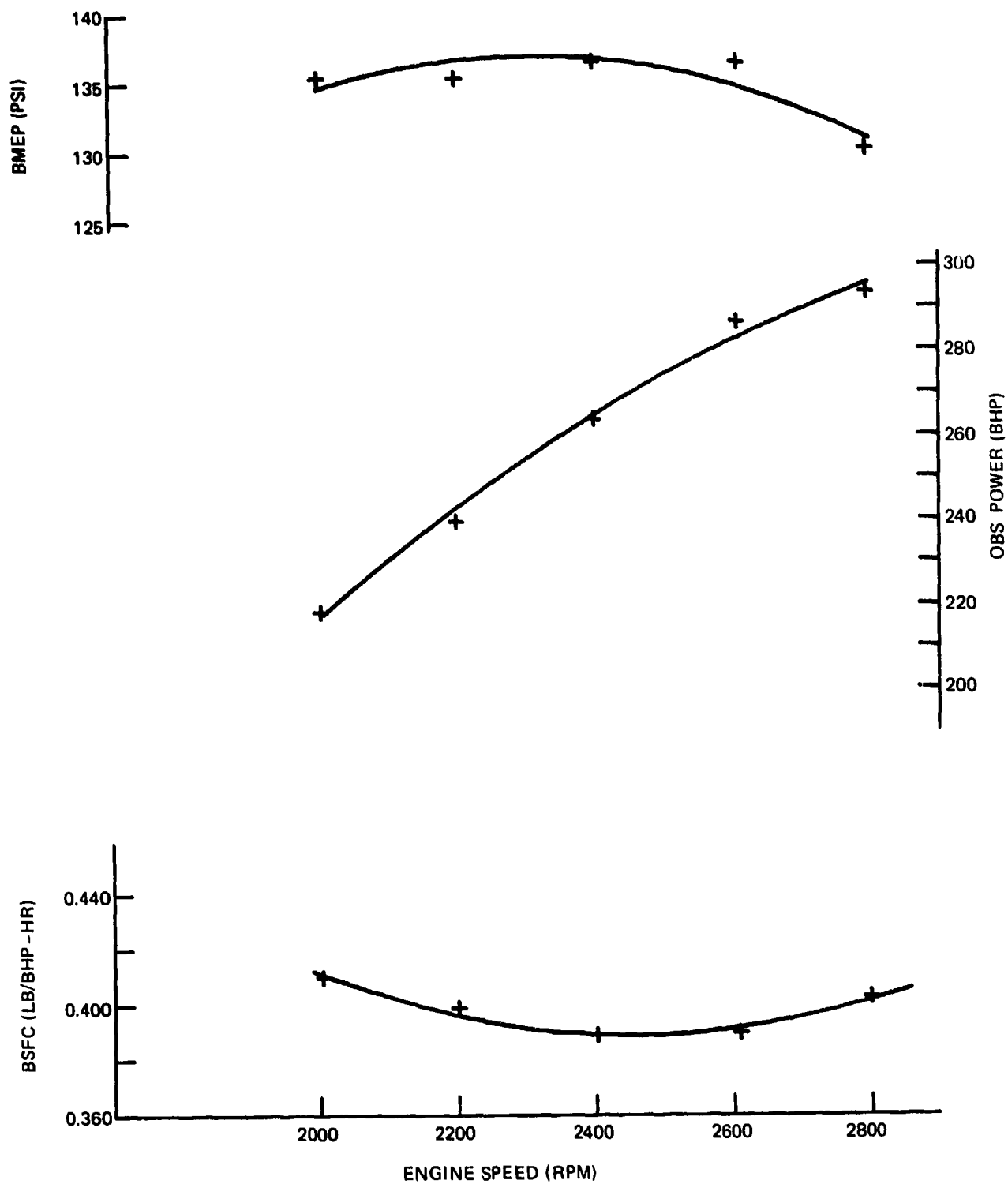
Measurements	Inches			
	Min	Max	Avg	Spec. Limits (1)
Connecting rod bearing clearance	0.0030	0.0034	0.0032	0.0016-0.0046
Cylinder liner block bore				
Taper	0.0003	0.0007	0.0005	0.0015 max
Out-of-round	0.0002	0.0007	0.0005	0.0015 max
Inside diameter	4.3569	4.3580	4.3574	4.3595 max
Cylinder Liners (installed)				
Taper	0.0001	0.0008	0.0005	0.0020 max (2)
Out-of-round	0.0001	0.0009	0.0003	0.0030 max (2)
Inside diameter	3.8756	3.8768	3.8762	3.8752-3.8767
Piston to liner fit	0.0074	0.0090	0.0082	0.0060-0.0095
Piston Diameter	3.8673	3.8685	3.8680	3.8669-3.8691
Fire Ring				
End gap	0.026	0.035	0.031	0.020-0.046
Side clearance	0.002	0.003	0.003	0.003-0.006
No. 1 Compression ring				
End gap	0.025	0.035	0.030	0.020-0.046
Side clearance	0.008	0.009	0.008	0.007-0.010
No. 2 & No. 3 Compression ring				
End gap	0.025	0.035	0.029	0.020-0.046
Side clearance	0.006	0.007	0.007	0.005-0.010
Oil rings				
End gap	0.012	0.022	0.018	0.010-0.025
Side Clearance	0.002	0.003	0.0025	0.0015-0.0055

- (1) Limits on new parts unless maximum wear limit specified.
(2) Wear limits with new liners in a used block.

6V53T FULL LOAD PERFORMANCE
BEFORE TEST

TEST NO.: C15136206-4

OIL: AL-6855-L



6V-53T ENDURANCE TEST
SUMMARY OF OPERATING DATA

TEST NO.: CI5136206-4

OIL: AL-6855-L

	2200 RPM			2800 RPM		
	<u>Avg</u>	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Engine Speed, rpm	2205	2199	2217	2805	2795	2815
Load, lb	456	440	474	435	417	464
Obs. Power, bhp	245	236	254	297	286	318
Fuel Rate, lb/hr	95.3	94.3	96.4	118.6	117.5	119.9
BSFC, lb/bhp-hr	0.389	0.374	0.404	0.399	0.376	0.417
<u>Temperatures, °F</u>						
Jacket In	154	150	160	154	148	160
Jacket Out	168	164	170	167	162	170
Oil Sump	236	230	246	247	242	250
Inlet Air (Compressor)	72	63	87	73	60	89
Airbox	232	224	240	278	270	290
Exhaust before Turbo	956	920	1000	982	960	1010
Exhaust after Turbo	824	800	870	845	820	880
Fuel at filter	86	79	90	88	85	93
<u>Pressures</u>						
Compressor Discharge	9.0	8.5	9.5	12.4	11.9	13.0
Blower Discharge	10.8	10.1	11.5	18.0	17.1	19.0
Exhaust Before Turbo	8.2	7.9	9.4	12.4	12.0	13.0

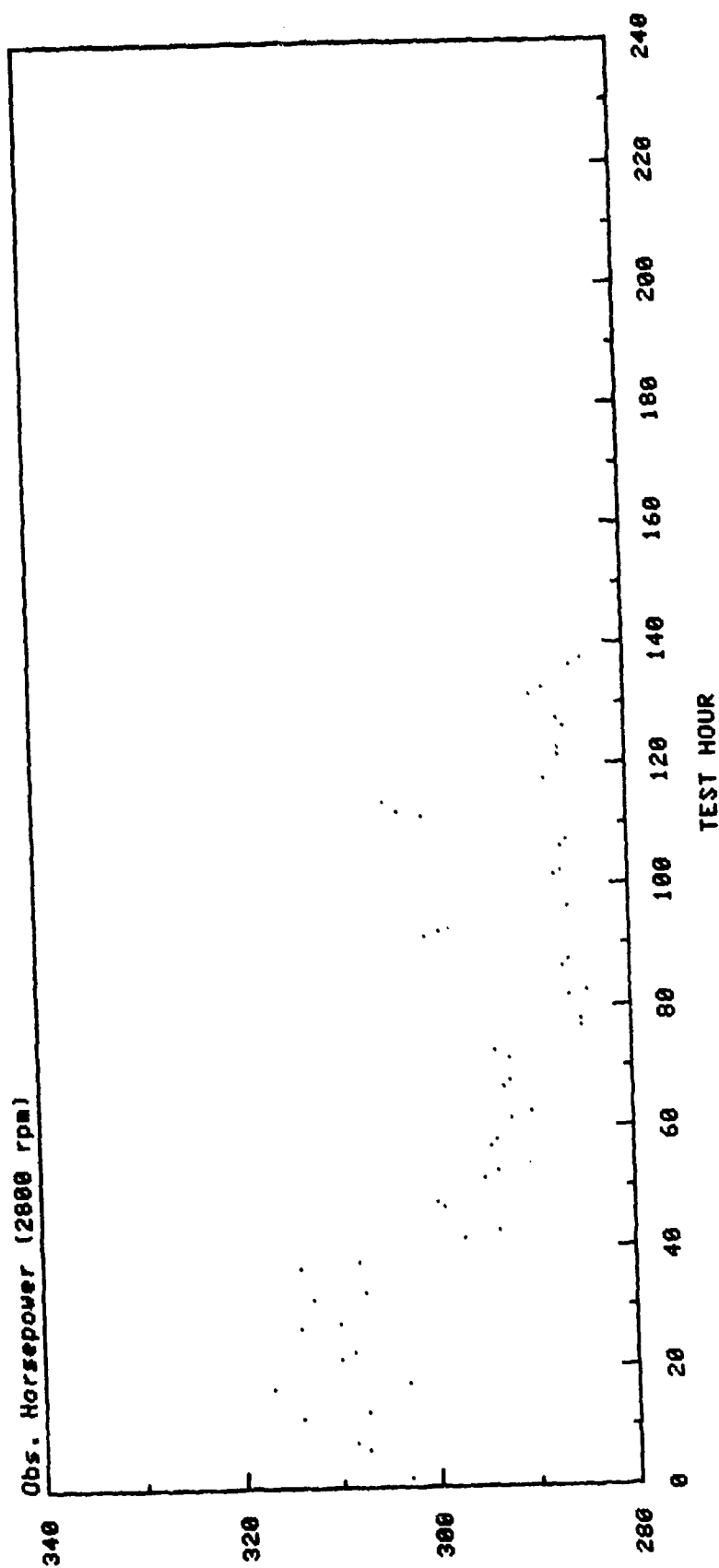
Oil Consumption (lb/hr
avg for 140 hr) 0.667

Unscheduled Shutdowns

1. At 4 hours - Oil Pump bypass leakage reduced oil pressure- lost 20 minutes
2. At 140 hours - High iron wear metals in oil and visual inspection of cylinder
1-left indicated incipient failure - Stopped test.

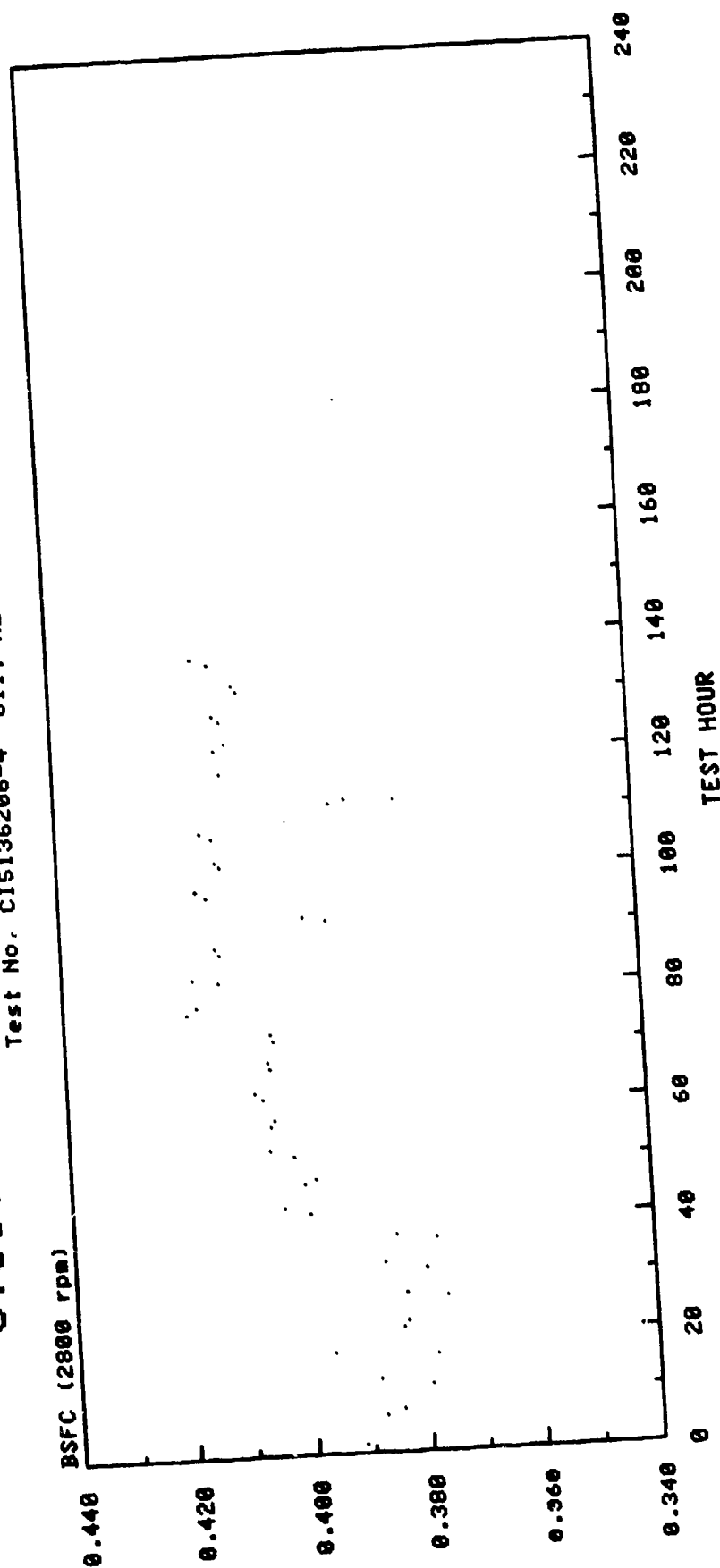
6V53T ENDURANCE TEST -240 HR. TRACKED

Test No. C15136206-4 Oil: AL-6855-L



6V53T ENDURANCE TEST -240 HR. TRACKED

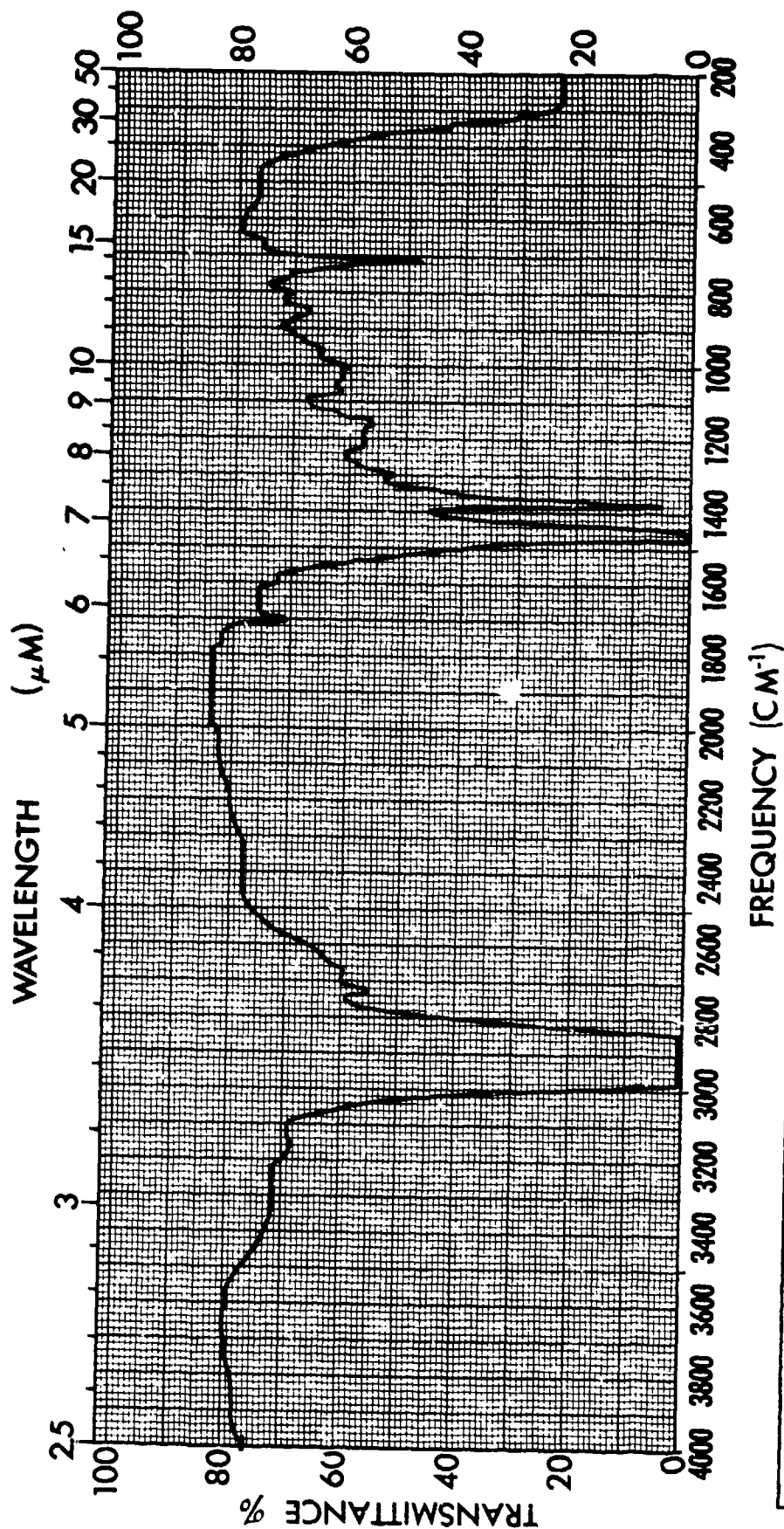
Test No. C15136206-4 Oil: AL-6855-L



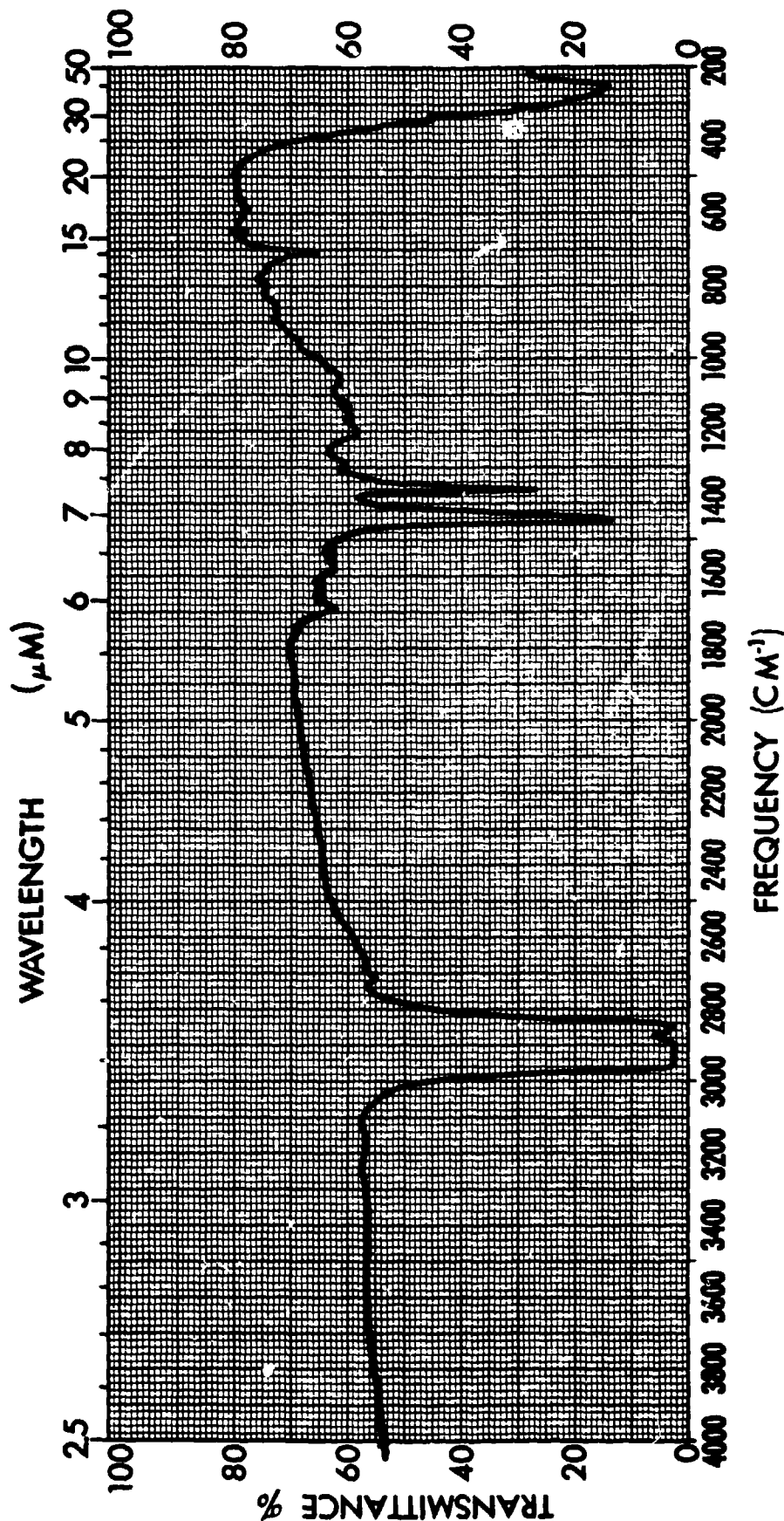
LUBRICANT ANALYSIS
6V53T - CI5136206 - 4
LUBRICANT: AL-6855-L
FUEL: 1-H CAT

Property	ASTM Procedure	New	20	40	60	80	100	120	140
K. Vis @40°C, cSt	D445	47.0*	47.03	50.60	52.85	53.33	55.30	56.69	47.21
K. Vis @100°C, cSt	D445	6.5	7.09	7.42	7.61	7.76	7.98	8.01	7.08
V.I.	D2270	103	108	108	107	110	111	108	107
TAN	D664	2.5	3.16	2.86	3.59	3.01	3.35	3.49	3.11
TBN	D2896	12.7	12.24	12.24	12.73	12.98	12.24	11.75	12.73
Insolubles, %	D893	0.02	0.04	0.12	0.49	0.22	1.35	1.59	0.06
Pentane B		0.01	0.03	0.10	0.21	0.19	1.21	1.36	0.06
Benzene B	D92	214	-	-	-	-	-	220	214
Flash Point, °C	D542	1.7	-	-	-	-	-	3.62	2.53
Carbon Residue, %	D874	1.7	-	-	-	-	-	2.23	1.91
Sulfated Ash, %	D287	28.3	-	-	-	-	-	26.7	27.4
Gravity, °API			97	139	177	221	236	258	260
Iron by XRF, PPM									
Cold Cranking Vis, cP	D2602	2180	-	-	-	-	-	3400	2560
At 0°F			-	-	-	-	-	19,300	13,900
At -20°F			-	-	-	-	-		

- Not Determined
*At 100°F

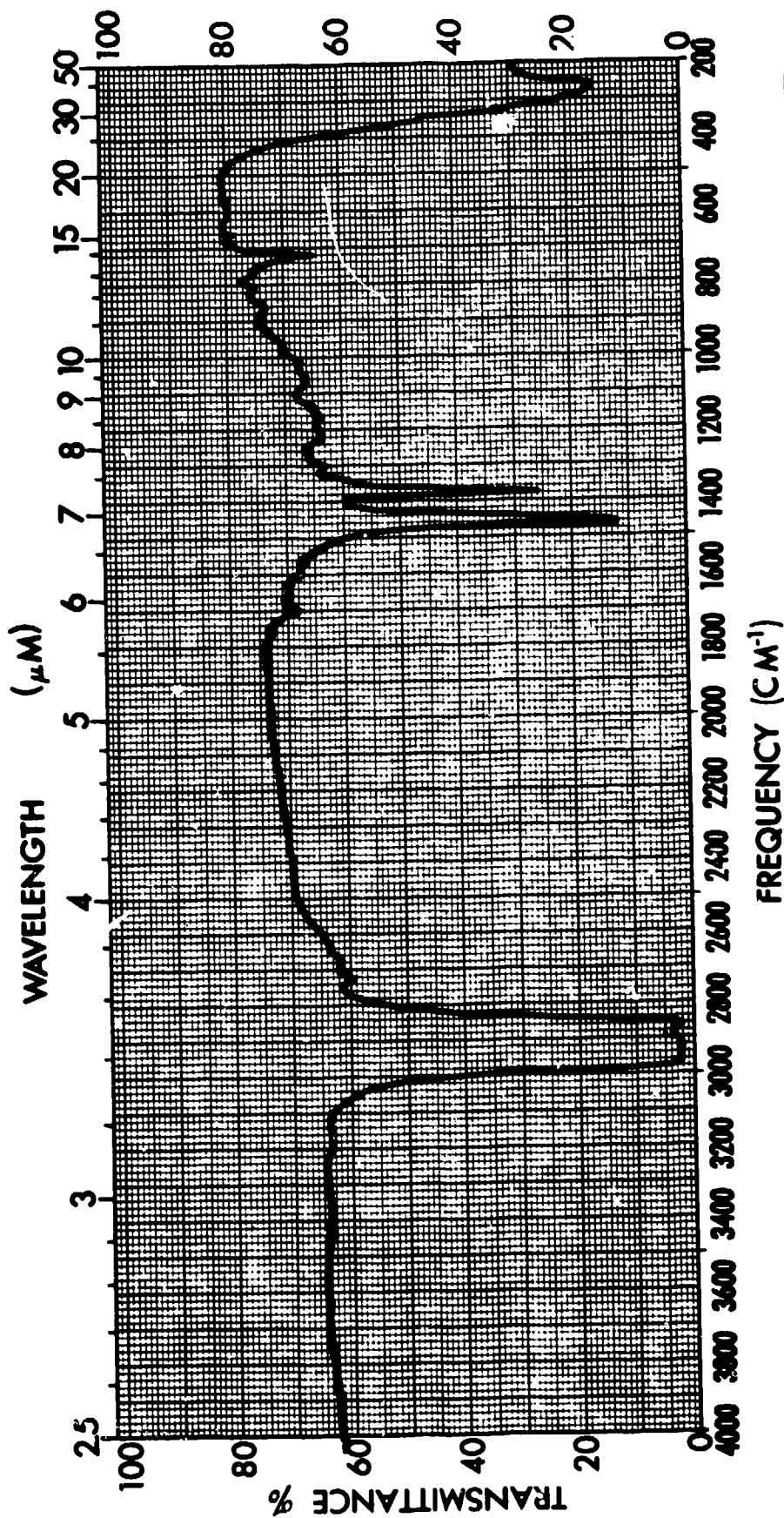


SPECTRUM NO. <u>1128</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6855-L</u>	_____	1. _____	_____
_____	PURITY _____	2. _____	_____
_____	PHASE _____	DATE <u>4-14-77</u>	_____
_____	THICKNESS <u>0.05</u>	OPERATOR <u>D.B.</u>	_____



B-11

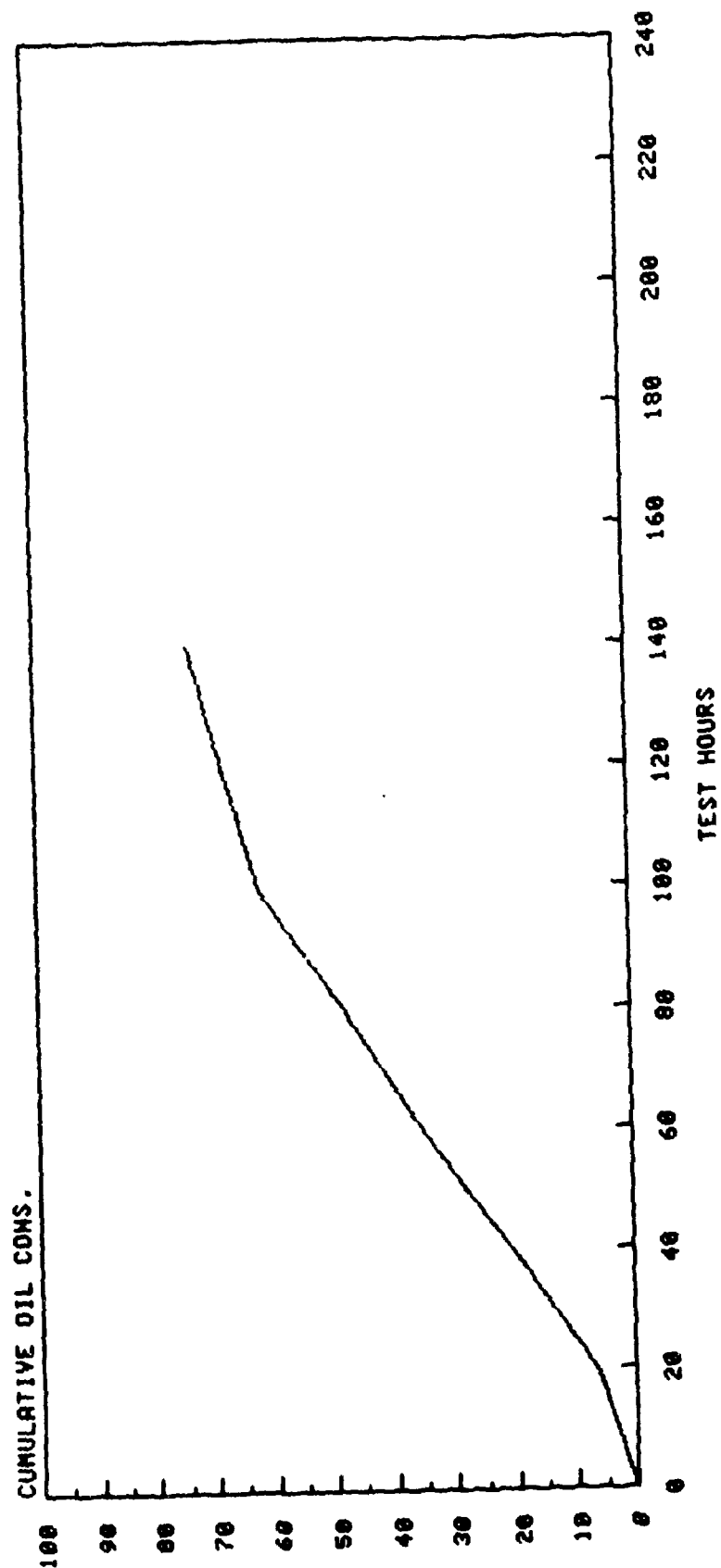
SPECTRUM NO. <u>1645</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6855-L</u>		1. _____	
6V-53-T 120 HR	PURITY _____	2. _____	
	PHASE _____	DATE <u>3/5/79</u>	
	THICKNESS <u>0.015</u>	OPERATOR <u>DDD</u>	



SPECTRUM NO. <u>1646</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6855-L</u>	_____	1. _____	_____
<u>6V-53-T</u> <u>140 HR</u>	PURITY _____	2. _____	_____
_____	PHASE _____	DATE <u>3/5/79</u>	_____
_____	THICKNESS <u>0.015</u>	OPERATOR <u>DDD</u>	_____

6V53T ENDURANCE TEST -CUM. OIL CONS.

Test No. CI5136286-4 OILIAL-6855-L



WEAR MEASUREMENTS
TEST NO. CI5136206-4
OIL: AL-6855-L
TEST HOURS: 140

Cylinder No.	Cylinder Liner I.D.					
	Perpendicular to Crankshaft			Parallel to Crankshaft		
	Top	Middle	Bottom	Top	Middle	Bottom
1L Before	3.8768	3.8768	3.8766	3.8760	3.8759	3.8766
	3.8698	3.8708	3.8777	3.8795	3.8792	3.8778
	Change	-0.0070	0.0011	0.0035	0.0033	0.0012
2L Before	3.8760	3.8762	3.8765	3.8759	3.8762	3.8764
	3.8789	3.8776	3.8766	3.8759	3.8762	3.8770
	Change	0.0029	0.0001	0.0000	0.0000	0.0006
3L Before	3.8759	3.8760	3.8763	3.8759	3.8759	3.8762
	3.8775	3.8775	3.8771	3.8763	3.8761	3.8765
	Change	0.0016	0.0008	0.0004	0.0002	0.0003
1R Before	3.8763	3.8763	3.8764	3.8764	3.8763	3.8764
	3.8770	3.8766	3.8771	3.8766	3.8766	3.8769
	Change	0.0007	0.0007	0.0002	0.0003	0.0005
2R Before	3.8759	3.8760	3.8763	3.8760	3.8760	3.8764
	3.8772	3.8770	3.8772	3.8808	3.8798	3.8784
	Change	0.0013	0.0009	0.0048	0.0038	0.0020
3R Before	3.8756	3.8760	3.8762	3.8762	3.8763	3.8764
	3.8766	3.8769	3.8769	3.8764	3.8765	3.8769
	Change	0.0010	0.0007	0.0002	0.0002	0.0005

WEAR MEASUREMENTS
ENGINE NO. 5136206-4
OIL: AL-6855-L
TEST HOURS: 140

<u>Cylinder No.</u>	<u>Rod Bearing Journal</u>		<u>Rod Bearing</u>	
	<u>AA</u>	<u>BB</u>	<u>F</u>	<u>R</u>
1L Before	2.7499	2.7499	2.7530	2.7530
After	2.7498	2.7498	2.7532	2.7531
Change	-0.0001	-0.0001	0.0002	0.0001
2L Before	2.7499	2.7499	2.7527	2.7527
After	2.7498	2.7498	2.7531	2.7531
Change	-0.0001	-0.0001	0.0004	0.0004
3L Before	2.7499	2.7498	2.7524	2.7524
After	2.7498	2.7498	2.7528	2.7528
Change	-0.0001	0.0000	0.0004	0.0004
1R Before	2.7498	2.7499	2.7524	2.7523
After	2.7498	2.7498	2.7529	2.7528
Change	0.0000	-0.0001	0.0005	0.0005
2R Before	2.7499	2.7499	2.7525	2.7525
After	2.7498	2.7498	2.7530	2.7530
Change	-0.0001	-0.0001	0.0005	0.0005
3R Before	2.7499	2.7499	2.7528	2.7528
After	2.7498	2.7498	2.7531	2.7532
Change	-0.0001	-0.0001	0.0003	0.0004

WEAR MEASUREMENTS
ENGINE NUMBER 5136206-4
OIL: AL-6855-L
TEST HOURS: 140

Piston No.	Piston Ring Gap, inches						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
1L Before	0.035	0.032	0.032	0.030	0.022	0.017	0.017
After	*	*	N.R.	0.037	0.078	0.035	0.038
Change	-	-	-	0.007	0.056	0.016	0.021
2L Before	0.030	0.029	0.026	0.025	0.019	0.020	0.019
After	0.038	0.030	0.028	0.026	0.035	0.028	0.028
Change	0.008	0.001	0.002	0.001	0.016	0.008	0.009
3L Before	0.031	0.030	0.027	0.028	0.021	0.017	0.017
After	0.033	0.035	0.028	0.030	0.038	0.025	0.024
Change	0.002	0.005	0.001	0.002	0.017	0.008	0.007
1R Before	0.034	0.035	0.035	0.035	0.018	0.012	0.013
After	0.044	0.038	0.038	0.038	0.034	0.018	0.020
Change	0.010	0.003	0.003	0.003	0.016	0.006	0.007
2R Before	0.026	0.025	0.029	0.030	0.022	0.018	0.018
After	0.032	0.025	0.030	0.032	0.045	0.028	0.028
Change	0.006	0.000	0.001	0.002	0.023	0.010	0.010
3R Before	0.030	0.028	0.025	0.029	0.019	0.018	0.017
After	0.032	0.028	0.026	0.030	0.035	0.028	0.026
Change	0.008	0.000	0.001	0.001	0.016	0.010	0.009

* Broken

N.R. - Not Removed

RATING DATA SHEET
C1-4

Test Run at AFLRL
Test Oil: AL-6855-L
Test Fuel: AL-8060-F
Test No.: CI5136206-4
Test Stand: 5
Engine No.: 5136206
Test Hours: 140
Date Started: 14 February 1979
Completed: 27 February 1979

A. Cylinder Liner Ratings

Intake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
1 L	05
2 L	01
3 L	01
1 R	05
2 R	01
3 R	02
Average	

Scuffing, Glazing and Lacquer*

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>Total</u>	<u>Glazing, %</u>	<u>Lacquer, %</u>
1 L	75	75	75	10	90
2 L	30	15	22	10	90
3 L	40	45	43	10	25
1 R	25	05	15	10	30
2 R	60	55	57	05	95
3 R	15	20	17	15	25
Average	41	34	38	10	59

*Ring Travel Area.

RATING DATA SHEET - CONTINUED
C1-4

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition			
	Ring			
	Fire	No. 1	No. 2	No. 3
1 L	* 100%B	* 100%B	Fy100%B	F 100%B
2 L	F 30%B	F 2%B	F 25%B	F 15%B
3 L	Sluggish 20%B	F 85%B	F 50%B	F 50%B
1 R	F 10%B	F 75%B	F 100%B	F 100%B
2 R	F 100%B	F 100%B	F 100%B	F 100%B
3 R	F 20%B	F 95%B	F 85%B	F 55%B

* Rings broken, + collapsed, y partially collapsed

Cylinder No.	Fire	Ring Groove Carbon Filling and Oil Groove Lacquer			Oil Groove Lacquer	
		Groove Filling, %			Upper	
		No.1	No.2	No.3	Upper	Lower
1 L	10	0	10	60	3.0	3.0
2 L	10	70	35	5	3.0	3.0
3 L	60	80	10	0	3.0	3.0
1 R	15	70	5	0	3.0	3.0
2 R	10	65	0	0	3.0	3.0
3 R	20	50	2	0	3.0	3.0

Cylinder No.	Land Description
1 L	Top Land-Distorted where ring broke (others normal)
2 L	Normal
3 L	Normal
1 R	Normal
2 R	3rd Land-Thrust side has plate melt (others normal)
3 R	Normal

Cylinder No.	Skirt	
	Side	
	Thrust	Anti-Thrust
1 L	6.0-10% Plate melt 30% Scuff	5.5-15% Melt 10% Scuff
2 L	5.5 Lt Scuff	5.5 Lt. Scratches
3 L	5.5 5% Plate melt 20% Scuff	5.5 Very Lt. Scratches
1 R	5.0 Lt Scratches	5.8 15% Plate melt and Scratches
2 R	4.8 Lt Scuffing	5.8 10% Plate melt and scuffing
3 R	5.5 Lt Scratches	5.9 Lt. Scuff and Scratches

RATING DATA SHEET - CONTINUED
C1-4

C. Other Ratings

Combustion Chambers

<u>Cylinder No.</u>	<u>Description</u>	<u>Cylinder No.</u>	<u>Description</u>
1 L	15% AHC	1 R	15% CHC 15 BHC 10 AHC
2 L	10% BHC 20 AHC	2 R	80% AHC
3 L	5% BHC 80% AHC	3 R	10% BHC 70 AHC

Valve Covers, Oil Pan and Cylinder Head Deck

Covers	Clean
Pan	Clean
Deck	Clean

Remarks

L - 1: When the two top rings broke, the top oil control ring was subjected to severe stress, resulting in more wear than usual.

D. Interim Inspections

Zero Test Hours

Inspection

1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

20 Test Hours

1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

40 Test Hours

1L	Light glazing at ports
2L	Light glazing at ports
3L	Light glazing at ports
1R	Fire ring black, light glazing at ports
2R	Light glazing at ports
3R	Light glazing at ports

60 Test Hours

1L	Light cyl. scuff and glazing
2L	Same as 40 hours
3L	Same as 40 hours
1R	Same as 40 hours
2R	Same as 40 hours
3R	Same as 40 hours

80 Test Hours

1L	Fire ring has section missing at gap
2L	Same as previous
3L	Same as previous
1R	No black showing on ring-rotated from inspection port
2R	Same as previous
3R	Same as previous

100 Test Hours

1L	Same as 80 hours
2L	Light scuffing on cylinder
3L	Same as 80 hours
1R	Light port deposits, otherwise same
2R	Same as 80 hours
3R	Same as 80 hours

120 Test Hours

1L	Some port plugging and more blowby deposits. Nos. 1 and 2 compression rings worn, fire ring stuck
2L	Liner shows light scuffing, glazing and lacquer, some port plugging
3L	Same as previous
1R	Same as previous
2R	More cylinder glaze
3R	Same as previous

140 Test Hours

1L	More piston deposits
2L	Same as previous
3L	Same as previous
1R	Fire ring stuck
2R	Same as previous
3R	Same as previous

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 140
 TEST LABORATORY AFRL
 LUBRICANT AL-6855-L

RATER Lyons DATE 3-5-79
 LABORATORY TEST NUMBER CI 5136206-4
 STAND NO 5 ENGINE NO. 5136206
 FUEL AL-8060-F

PISTON NO. 1 Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME %	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD* RATING	
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC 1.00			75	75.00					10	10.00	75	75.00						
	MHC 0.75																		
	MC 0.50			25	12.50	20	10.00					25	12.50						
	LC 0.25	100	25.00			30	7.50			90	22.50			50	15.00	20	5.00		
	VLC 0.15					50	7.50												
CARBON RATING		25.00		87.50		25.00				32.50		87.50		15.00		5.00			
LACQUER	BL 0.100							50	5.00					40	4.00	5	.50		
	DBrL 0.075							50	3.75									100	7.50
	AL 0.050																		
	LAL 0.025															75	1.875		
	VVAL 0.010																		
LACQUER RATING																			
CLEAN 0																			
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		25.00		87.50		25.00		8.75		32.50		87.50		19.00		7.375			7.50

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 140
 TEST LABORATORY AFLRL
 LUBRICANT AL-6855-L

RATER E. Lyons DATE 3-6-79
 LABORATORY TEST NUMBER CI5136206 - 4
 STAND NO. 5 ENGINE NO. 5136206
 FUEL AL-8060-F

PISTON NO. 2 Right

LUBRICANT		FUEL		AL-8050-F		AL-6855-L		NO. 1 GROOVE, VOLUME %		PISTON WTD * RATING		279.2	
DEPOSIT TYPE		DEPOSIT FACTOR		GROOVES				LANDS				UNDER-CROWN	
				NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4		
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00											
	MHC	0.75											
	MC	0.50											
	LC	0.25											
	VLC	0.15											
CARBON RATING		19.00	85.00										
LACQUER	BL	0.100											
	DBrL	0.075											
	AL	0.050											
	LAL	0.025											
	VLAL	0.010											
LACQUER RATING													
CLEAN 0													
ZONAL RATING													
LOCATION FACTOR													
WEIGHTED RATING		19.00	85.00	10.00	5.00	57.50	81.50	10.85	2.875				7.50

NC. 1 GROOVE, VOLUME-%

PISTON WTD* RATING 279.2

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 140
 TEST LABORATORY AFLRL
 LUBRICANT AL-6855-I

RATER Lyons DATE 3-6-79
 LABORATORY TEST NUMBER CI5136206-4
 STAND NO. 5 ENGINE NO. 5136206
 FUEL AL-8060-F

PISTON NO. 3 Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC	1.00								20	20.00	80	80.00		
	MHC	0.75													
	MC	0.50	50	25.00	35	17.50	5	2.50		65	32.50		25	12.50	
	LC	0.25	10	2.50						15	3.75	10	2.50	35	8.75
	VLC	0.15	40	6.00							10	1.50	40	6.00	
CARBON RATING		33.50	82.50	2.50		56.25	84.00	27.25							
LACQUER	BL	0.100													
	DB/L	0.075						95	9.50						
	AL	0.060												100	7.50
	LAL	0.025											100	2.50	
	VLAL	0.010													
LACQUER RATING					2.50										
CLEAN	0							9.50						2.50	7.50
ZONAL RATING															
LOCATION FACTOR															
WEIGHTED RATING		33.50	82.50	12.00	2.50	56.25	84.00	27.25	2.50						
*WEIGHTED TOTAL DEPOSITS														2.50	7.50

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 140
 TEST LABORATORY AFRL
 LUBRICANT AL-6855-L

RATER Lyons DATE 3-5-79
 LABORATORY TEST NUMBER CI5136206-4
 STAND NO. 5 ENGINE NO. 5136206
 FUEL I-H CAT AL-8060-F

PISTON NO. 1 Left

NO. 1 GROOVE, VOLUME %	
PISTON WTD* RATING	394.5

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN		
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4				
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT			
CARBON	HC	1.00							10	10.00	50	50.00	65	65.00	75	75.00	95	95.00		
	MHC	0.75							20	15.00										
	MC	0.50																		
	LC	0.25									50	12.50	10	2.50						
	VLC	0.15	100	15.00	100	15.00	100	15.00	70	10.50			15	2.25	15	2.25				
CARBON RATING		15.00		15.00		15.00		35.50		62.50		69.75		77.25		95.00				
LACQUER	BL	0.100														5	.50			
	DBrL	0.075										10	.75	10	.75			100	7.50	
	AL	0.050																		
	LAL	0.025																		
	VLAL	0.010																		
LACQUER RATING												.75		.75		.50		7.50		
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING		15.00		15.00		15.00		35.50		62.50		70.50		78.00		95.50		7.50		

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 2 Left

TEST PROCEDURE Tracked
TEST HOURS 140
TEST LABORATORY AFLRL
LUBRICANT AL-6855-L

RATER Lyons DATE 3-5-79
LABORATORY TEST NUMBER CI5136206-4
STAND NO. 5 ENGINE NO. 5136206
FUEL AL-8060-F

TEST HOURS		STAND NO. 5		ENGINE NO.		NO 1 GROOVE, VOLUME-%		PISTON WTD* RATING		UNDER-CROWN	
TEST LABORATORY AFRL		FUEL AL-8060-F									
LUBRICANT AL-6855-L											

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked
 TEST HOURS 140
 TEST LABORATORY AFLRL
 LUBRICANT AL-6852-L

RATER LYONS DATE 3-5-79
 LABORATORY TEST NUMBER G1513206-4
 STAND NO. 5 ENGINE NO. 5136206
 FUEL AL-8060-F

PISTON NO. 3 Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME-%	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC	10	10.00	100	100.00	20	20.00			90	90.00	75	75.00	40	40.00				
	MHC																		
	MC	90	45.00							10	2.50	25	6.25						
	LC																		
	VLC													55	8.25	50	7.50		
CARBON RATING		55.00	100.00	20.00		92.50	81.25	48.25	7.50										
LACQUER	BL			80	8.00	35	3.50												
	DBL																25	1.875	100
	AL						65	3.25											
	LAL															5	.125	25	.625
	VIAL																		
LACQUER RATING				8.00	6.75											.125	2.50		7.50
CLEAN																			
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		55.00	100.00	28.00	6.75	92.50	81.25	48.375	10.00										7.50

*WEIGHTED TOTAL DEPOSITS

RING STICKING C1-4

Engine Model 6V53T Serial No. CI 5136206-4 Date 3-5-79
 Fuel AL-8060-F Lubricant AL-6855-L Observer E. Lyons

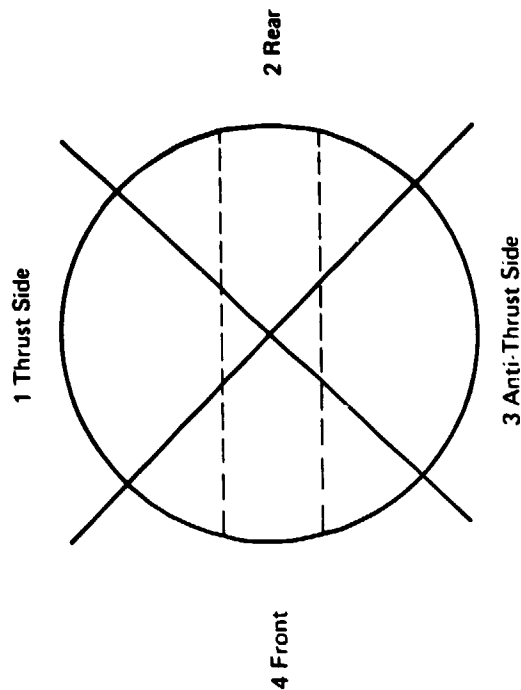
Ring No.	Piston Number					
	1L	2L	3L	1R	2R	3R
1	Broken Partially Collapsed	F	Sluggish	F	F	F
2 Not Removed	Broken Collapsed	F	F	F	F	F
3 Not Removed	Free Collapsed	F	F	F	F	F
4	F	F	F	F	F	F

Indicate by letter - Free or Sluggish, or by number and letter - percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

PISTON GROOVE INSIDE DIAMETER - % RING SUPPORTING CARBON C1-4

Engine Model AL-8060-F 6V53T Serial No. 5136206-4 Date 3-5-79
 Fuel AL-8060-F Lubricant AL-6855-L Observer E. Lyons

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	0	0	0	0	0	0
	2	0	0	100	50	0	25
	3	0	80	30	10	0	0
	4	0	0	100	50	20	25



VALVE DEPOSITS CI-4

Engine Model 6V53T Serial No. CI 5136206-4 Date 3-5-79
 Fuel AL-8060-F Lubricant AL-6855-L Observer E. Lyons

Cylinder Number																						
		1L			2L			3L			1R			2R			3R					
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LARQ			
Head*	INT	A	-	B	-	C	H	C					A	L	L							
	EXH																					
Face	INT	C	L	E	A	N						#	9		L	A	C	Q				
	EXH																					
Tulipt	INT	L	I	G	H	T		C	A	R	E	O	N			+	#	9	L	A	C	Q
	EXH																					
Stem	INT	9		L	A	C	Q		T	O				C	L	E	A	N				
	EXH																					

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S (Page 5).

Lacquer: Pages 4, 36 and 37.

EXHAUST VALVE SURFACE CONDITIONS C1-4

Engine Model 6V53T Serial No. CI 5136206 -4 Date 3-5-79
 Fuel AL-8060-F Lubricant AL-6855-F Observer E. Lyons

	1L	2L	3L	1R	2R	3R
Freeness in Guide	F	F	F	F	F	F
Head	N	N	N	N	N	N
Face	N	N	N	N	N	N
Seat	N	N	N	N	N	N
Stem	N	N	N	N	N	N
Tip	N	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

TAPPETS, CAMS, AND ROCKER ARMS C1-4

Engine Model 6V53T Serial No. CI 5136206-4 Date 3/5/79
 Fuel AL-8060-g Lubricant AL-6855-L Observer E. Lyons

		Cylinder Number							
		1L	2L	3L	1R	2R	3R		
Tappet Deposit	INT	C	L	E	A	N			
	EXH								
Tappet Surface Condition	INJ	N	N	N	N	N	N	N	
	INT								
	EXH	LC Scratches	N	N	N	N	N	N	
Cam Lobes		N	N	N	N	N	N	N	
Rocker Arms	Tip	INT							
		EXH	N	N	N	N	N	N	
	Bushings	INT							
		EXH	N	N	N	N	N	N	
	Shaft	INT							
		EXH	N	N	N	N	N	N	

Lacquer: Pages 4, 36 and 37 of Manual
 See Pages 1, 2, 16 through 23, and 54 through 65.

SURFACE CONDITION C.1-4

Engine Model	6V53T	Serial No.	CI 5135206-4	Date	3-6-79
Fuel	AL-8060-F	Lubricant	AL-6855-L	Observer	E. Lyons

Bearing No.	L 1	L 2	L 3	R1	R2	R3	7
Main-Bearing	Scratched Metal Lift-off bottom half	Same as Copper show- ing metal lifting off deep scratches		Copper showing			
-Journal	N	N	N	N			
Rod-Bearing	Some Scratches	N	Scratched Copper Shows	Light Scratches			
-Journal	N	N	N	N			
Piston Pin	N	N	*	N			
Bushing	N	N	*	N			

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.
 *Looks like pin was tight in bushing light gall on pin bushing.

CONDITION OF PISTON AND CYLINDER LINER

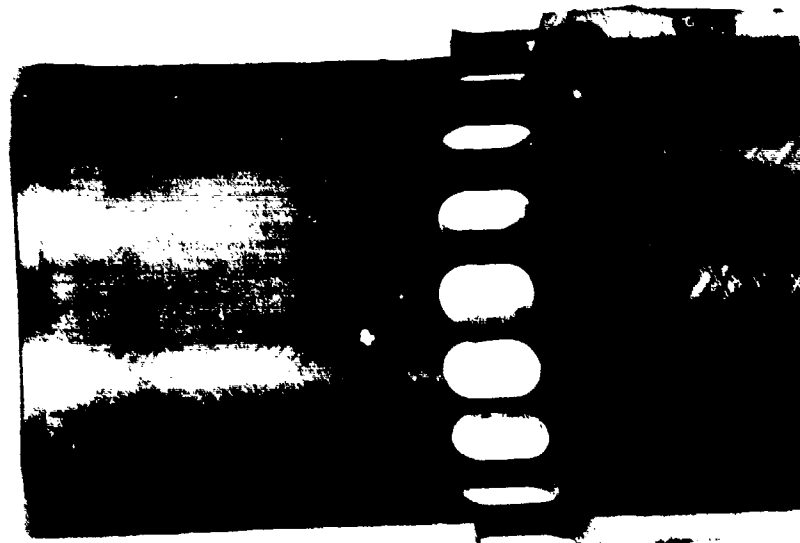
TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



1-RIGHT THRUST

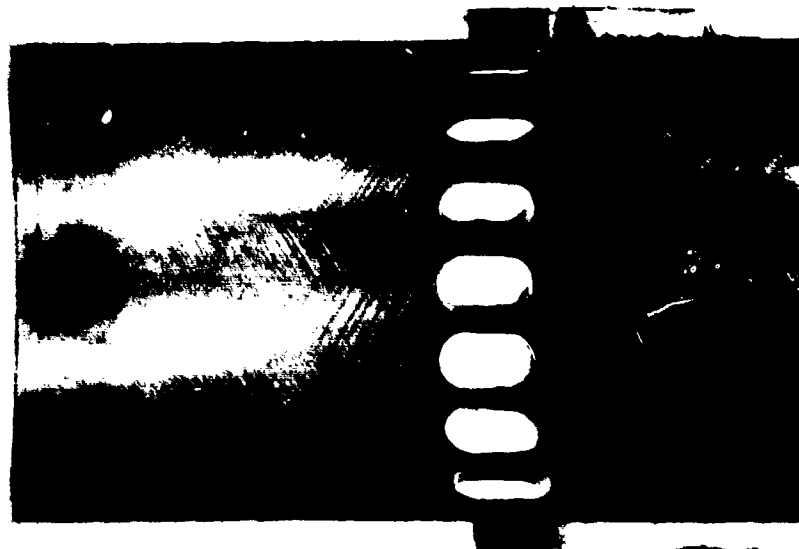


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



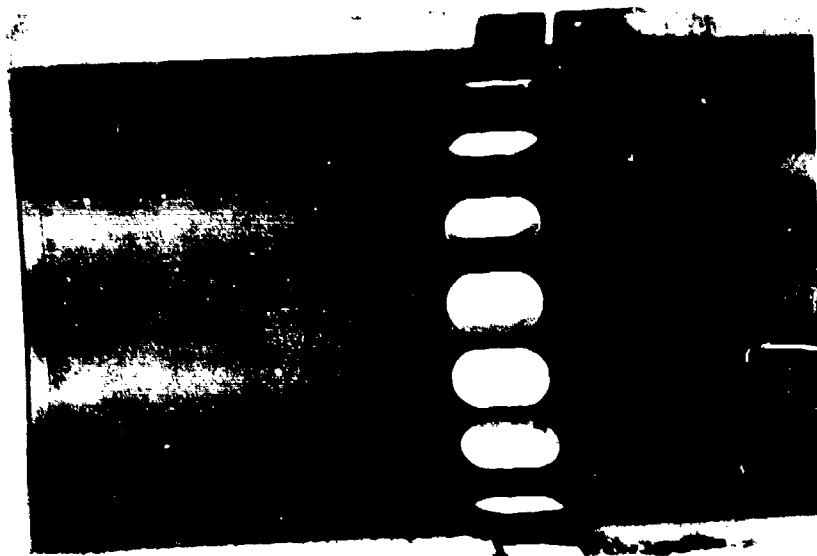
1-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



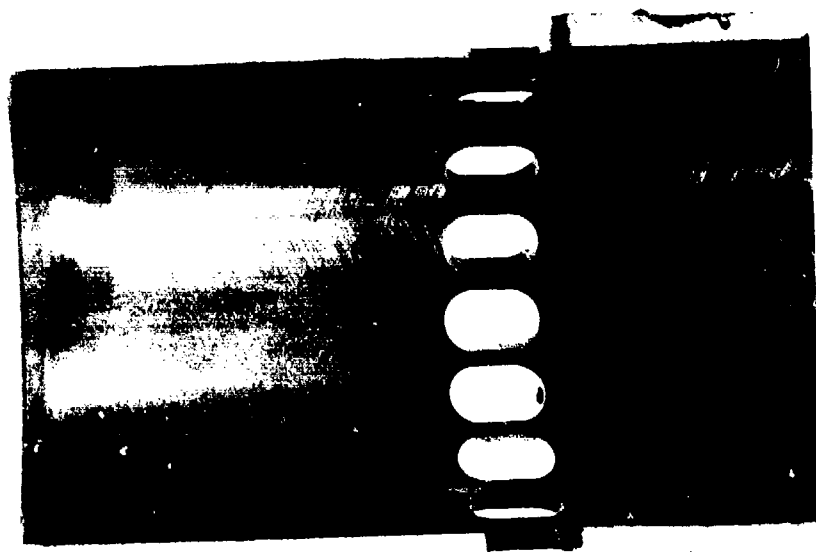
2-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



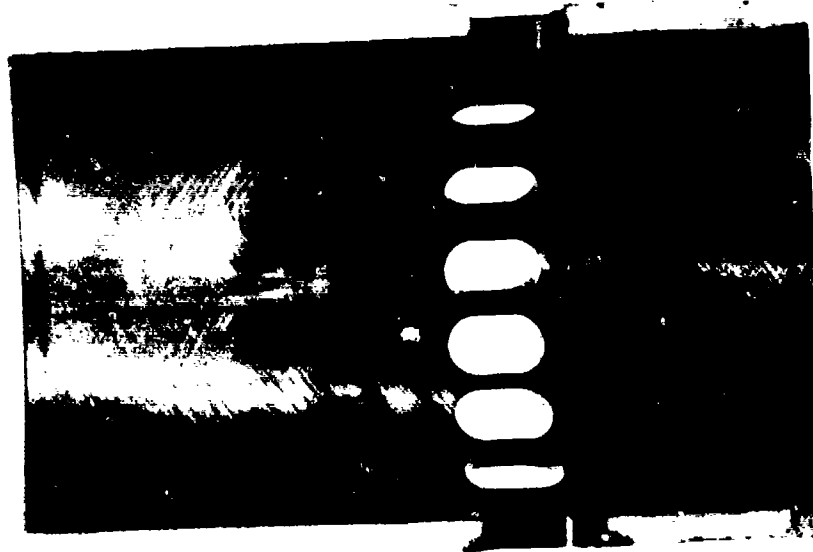
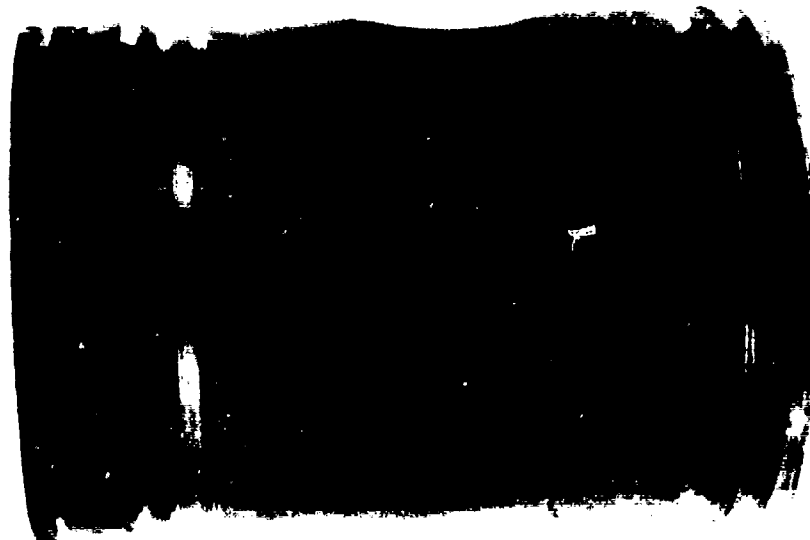
2-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



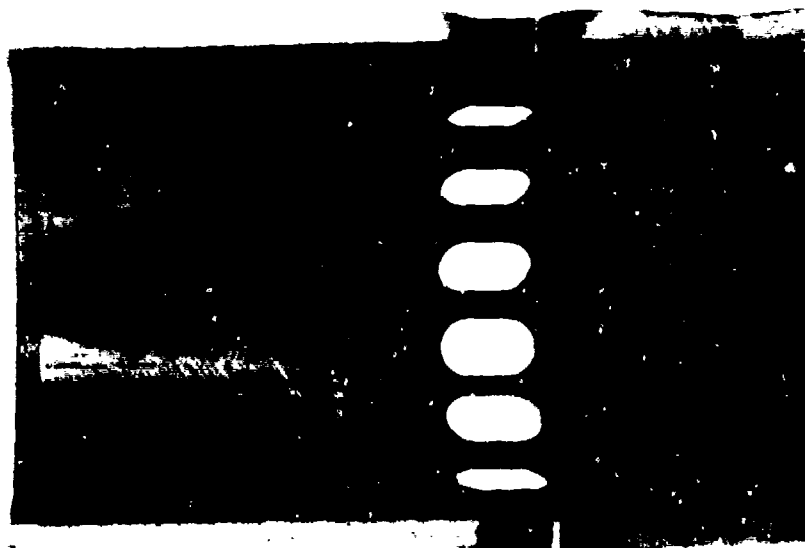
3-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



3-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

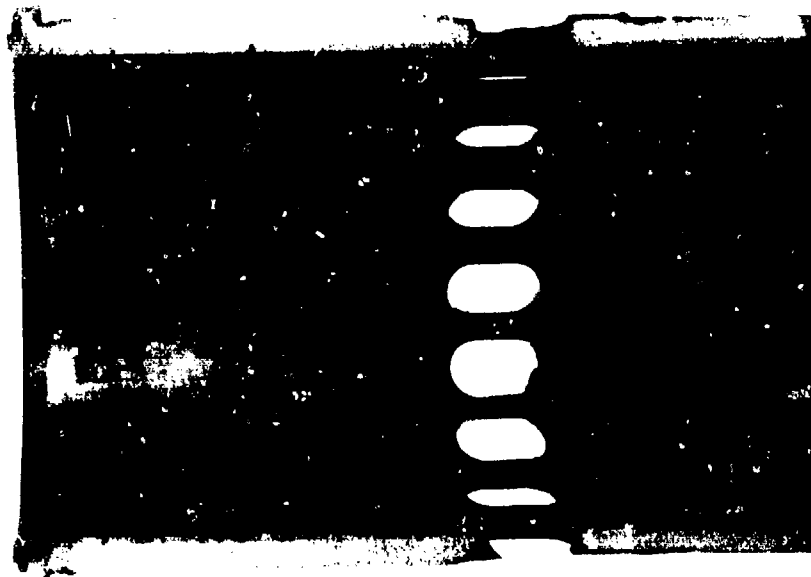
TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



1-LEFT THRUST

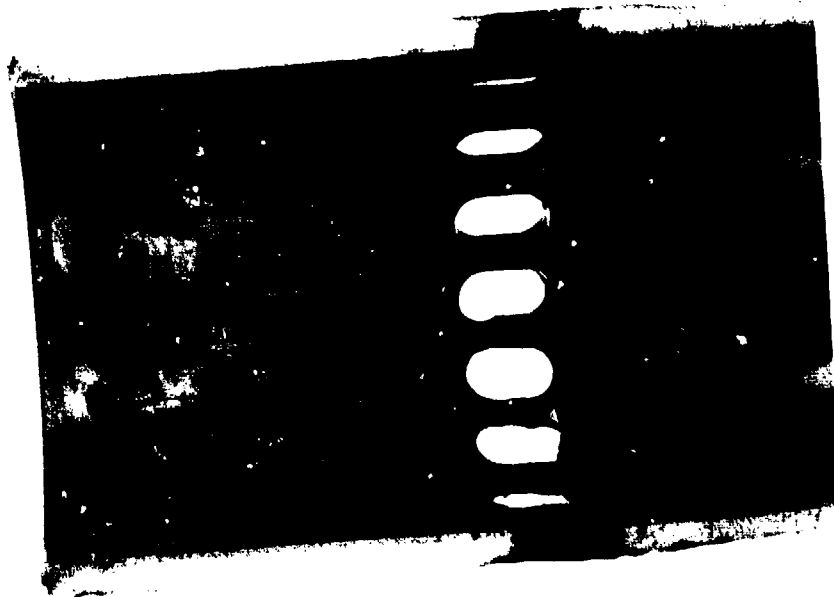
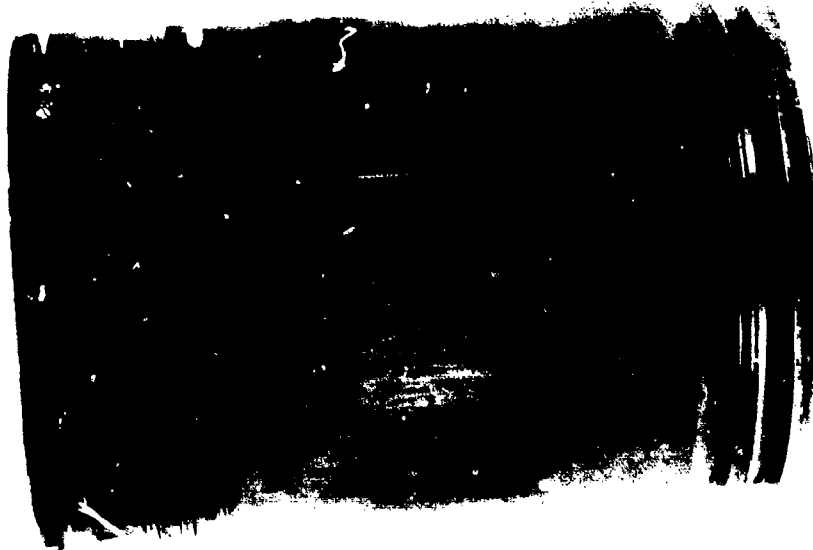


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



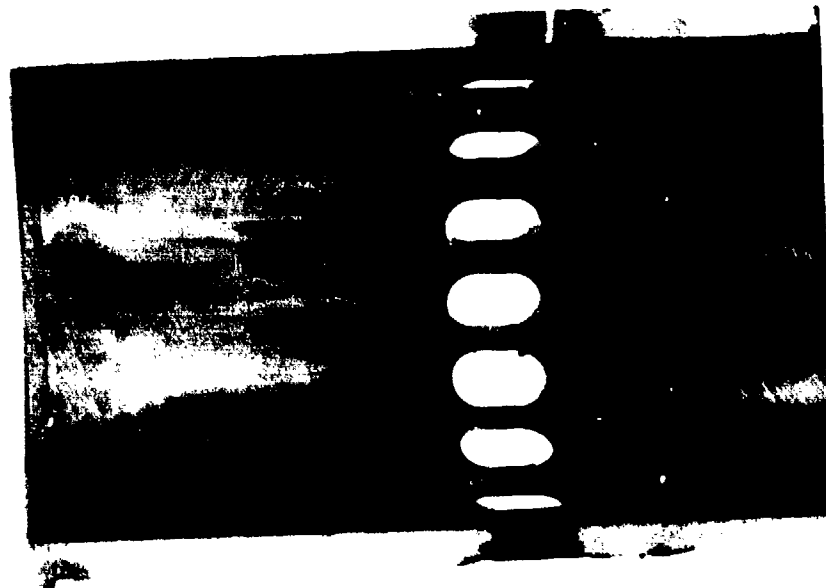
1-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TES. TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



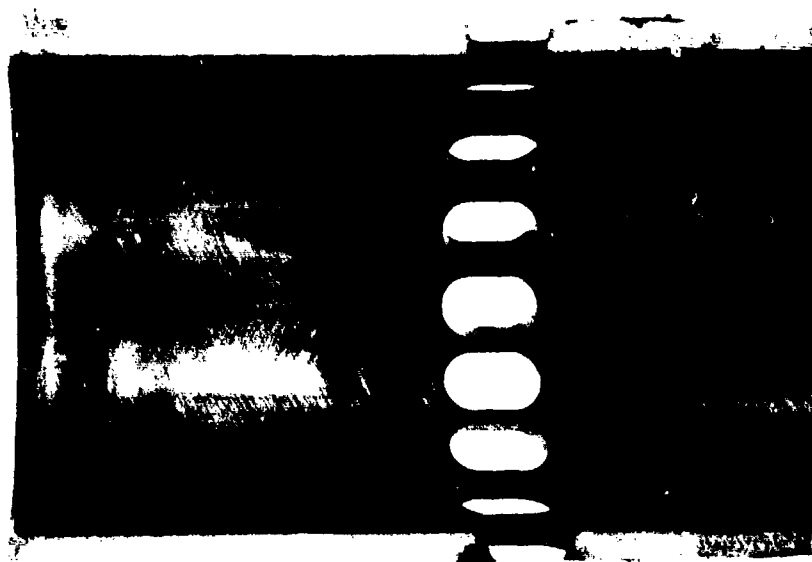
2-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



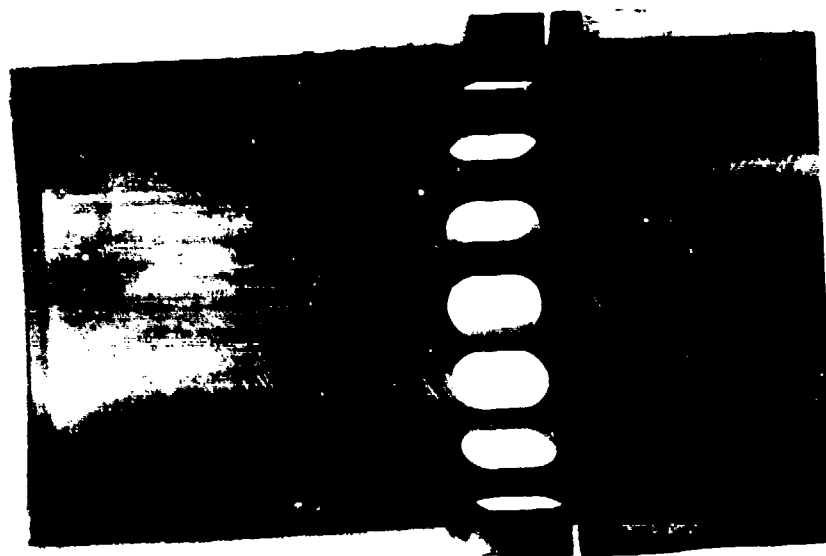
2-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



3-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 140 HOURS

TEST NO.: CI5136208-4

OIL: AL-6855-L



3-LEFT ANTI-THRUST

B-45

CONDITION OF PISTON RING FACE

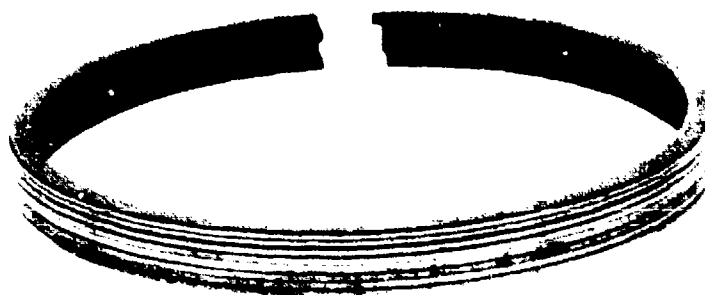
TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

OIL: AL-6855-L



1 RIGHT



2 RIGHT



3 RIGHT

B-46

CONDITION OF PISTON RING FACE

TEST TIME: 140 HOURS

TEST NO.: CI5135206-4

OIL: AL-8855-L



1 LEFT



2 LEFT



3 LEFT

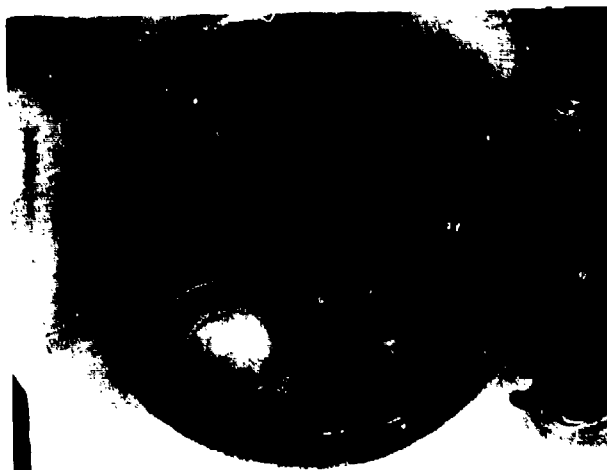
B-47

CONDITION OF CYLINDER HEAD

TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

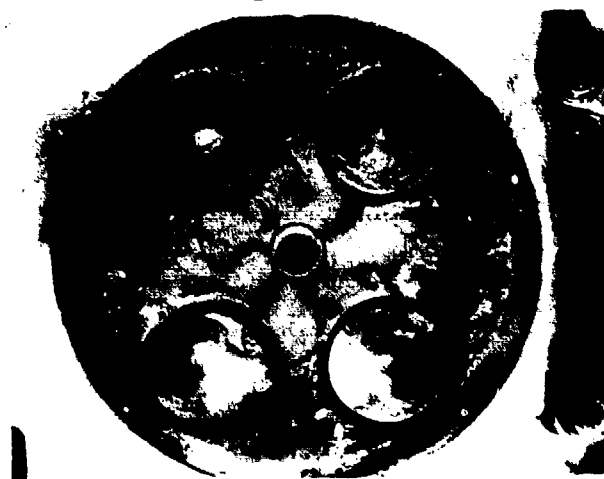
OIL: AL-6855-L



1 RIGHT



2 RIGHT



3 RIGHT

B-48

CONDITION OF CYLINDER HEAD

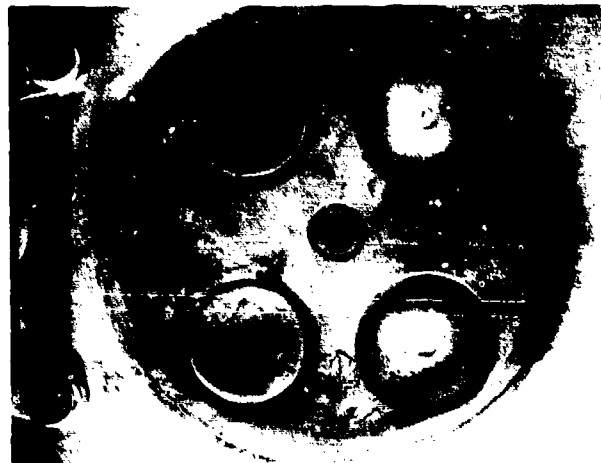
TEST TIME: 140 HOURS

TEST NO.: CI5136206-4

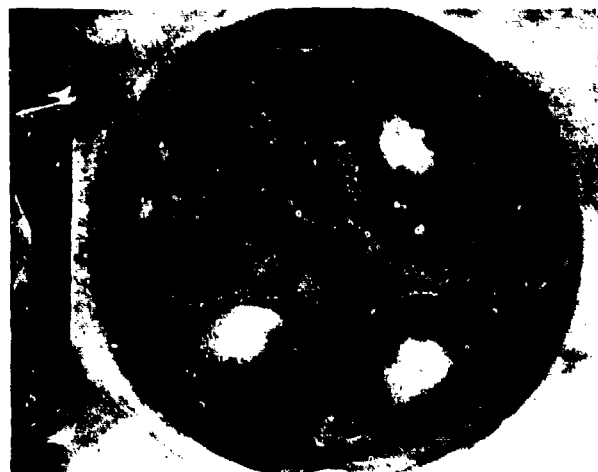
OIL: AL-6855-L



1 LEFT



2 LEFT



3 LEFT

B-49

APPENDIX C

**ENGINE-LUBRICANT COMPATIBILITY TEST #5
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE**

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED VEHICLE CYCLE
USING 6V53T DIESEL ENGINE

Test Lubricant: AL-6947-L
Engine Test Number: CI 5136206-5
Date Completed: 2 May 1979

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

By

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

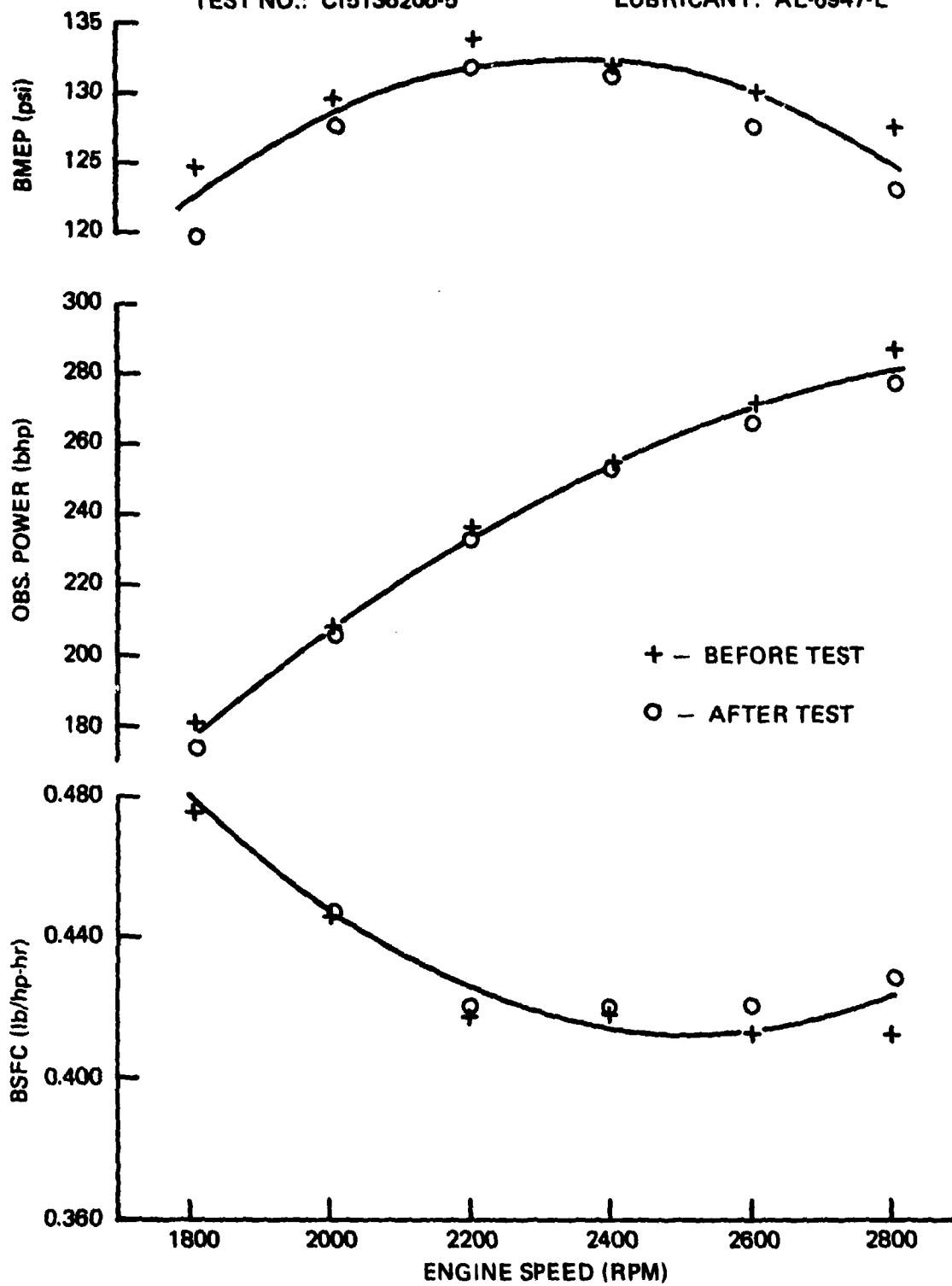
6V53T
BUILD-UP ENGINE MEASUREMENTS
CI 5136206-5

Measurements	Inches			Spec. Limits (1)
	Min	Max	Avg	
Cylinder liner block bore				
Taper	0.0000	0.0002	0.0001	0.0015 max
Out-of-round	0.0000	0.0002	0.0001	0.0015 max
Inside diameter	4.3570	4.3575	4.3573	4.3595 max
Cylinder Liners (installed)				
Taper	0.0001	0.0008	0.0004	0.0020 max (2)
Out-of-round	0.0000	0.0003	0.0001	0.0030 max (2)
Inside diameter	3.8753	3.8762	3.8758	3.8752-3.8767
Piston to liner fit	0.0067	0.0088	0.0074	0.0060-0.0095
Piston Diameter	3.8659	3.8688	3.8676	3.8669-3.8691
Fire Ring				
End gap	0.027	0.036	0.033	0.020 -0.046
Side clearance	0.003	0.003	0.003	0.003 -0.006
No. 1 Compression ring				
End gap	0.028	0.034	0.031	0.020 -0.046
Side clearance	0.008	0.009	0.008	0.007 -0.010
No. 2 & No. 3 Compression ring				
End gap	0.025	0.036	0.030	0.020 -0.046
Side clearance	0.006	0.007	0.006	0.005 -0.010
Oil rings				
End gap	0.016	0.022	0.019	0.010 -0.025
Side clearance	0.002	0.003	0.002	0.0015-0.0055

(1) Limits on new parts unless maximum wear limit specified.

(2) Wear limits with new liners in a used block.

6V53T FULL LOAD PERFORMANCE
TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L

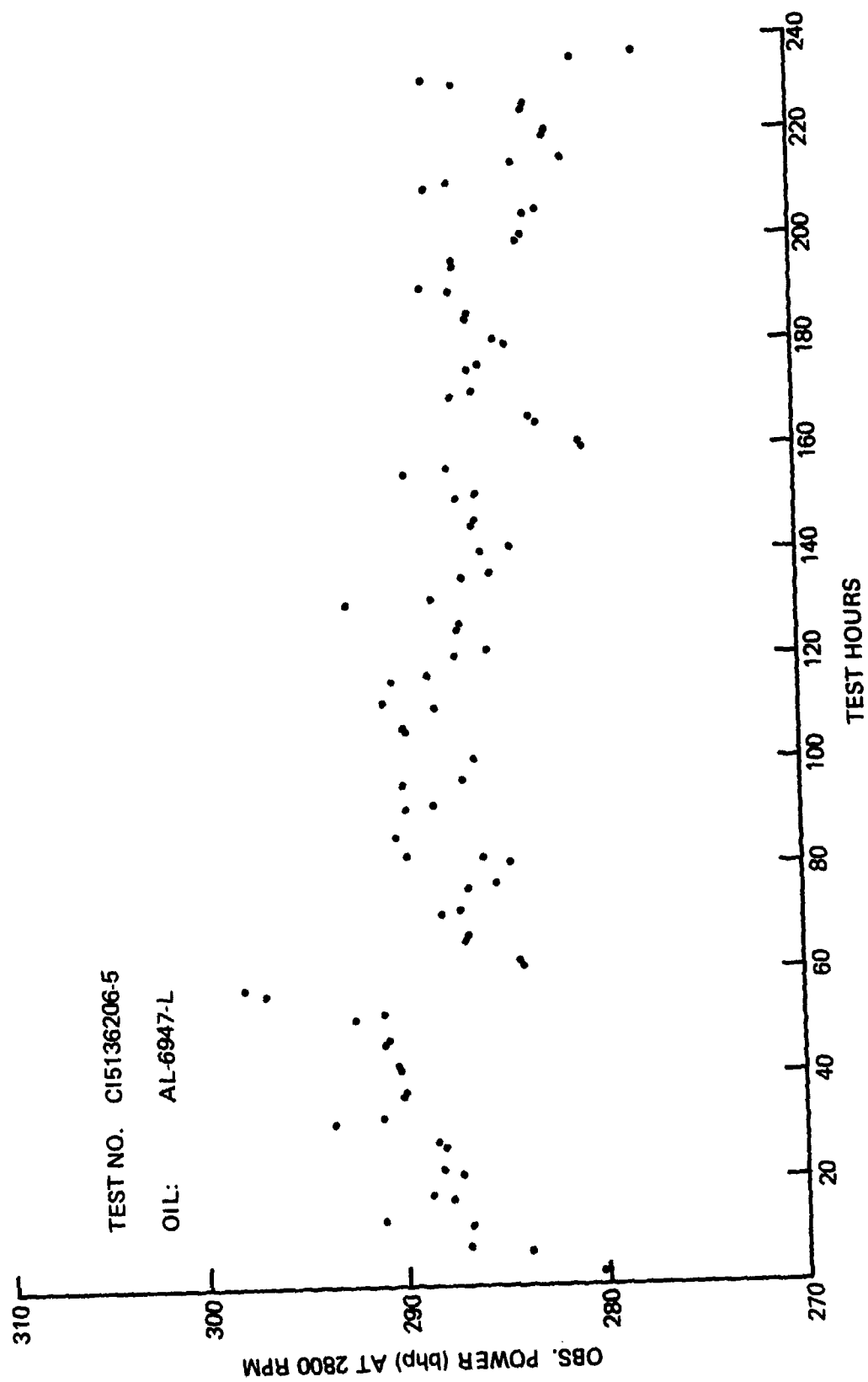


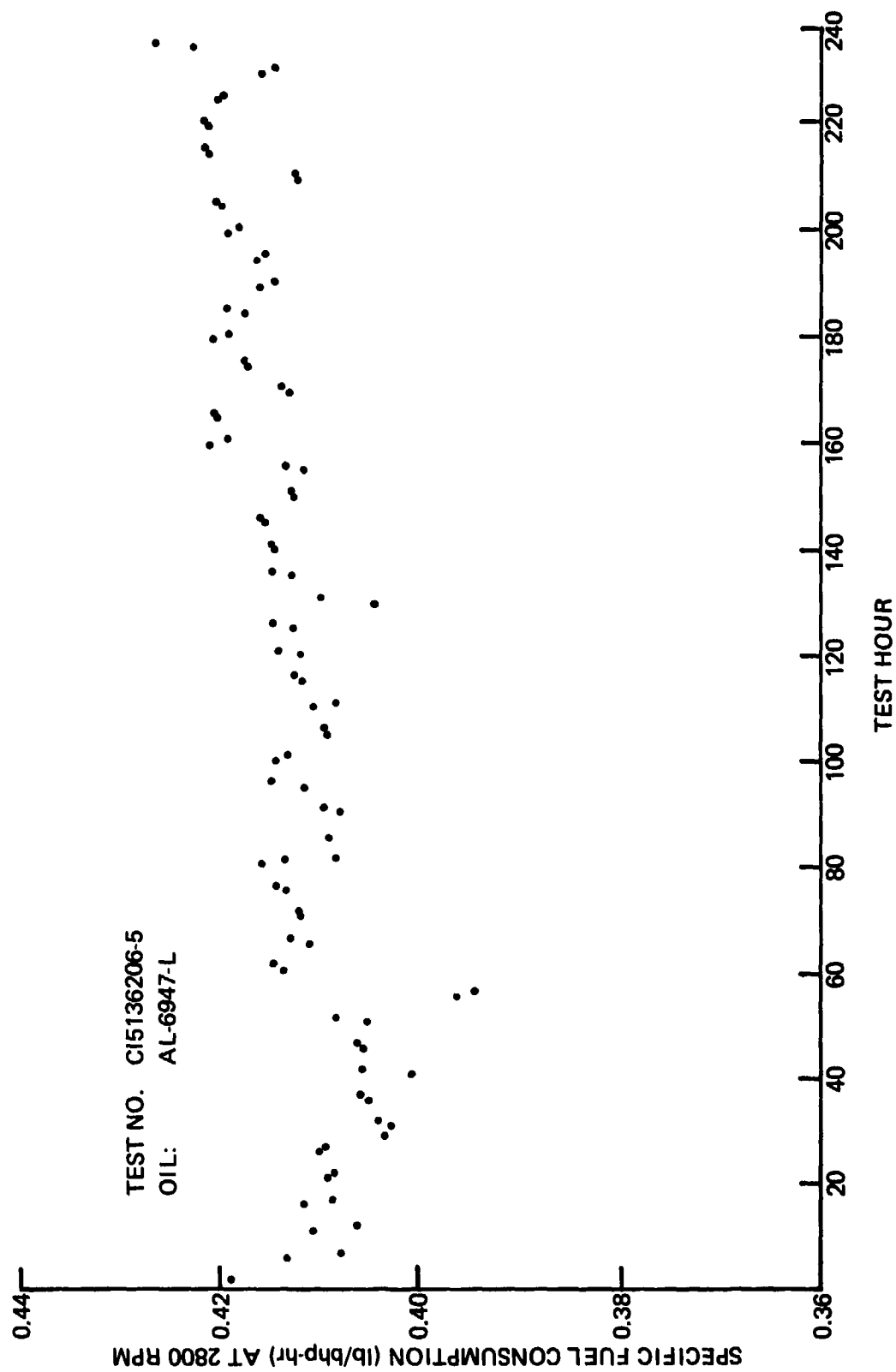
6V53T ENDURANCE TEST
SUMMARY OF OPERATING DATA

Test No.: CI 5136206-5

Oil: AL-6947-L

	2200 RPM			2800 RPM		
	Avg	Min	Max	Avg	Min	Max
Engine Speed, rpm	2205	2199	2209	2804	2799	2810
Load, lb	448	436	464	420	406	436
Obs. Power, bhp	241	234	249	287	278	298
Fuel Rate, lb/hr	98.3	96.9	99.3	118.5	116.4	120.0
BSFC, lb/bhp-hr	0.408	0.392	0.419	0.413	0.395	0.426
<u>Temperatures, °F</u>						
Jacket In	148	72	156	139	67	145
Jacket Out	162	149	166	152	140	160
Oil Sump	247	237	250	248	244	250
Inlet Air (compressor)	81	75	92	82	73	90
Airbox	258	232	280	299	281	311
Exhaust before Turbo	1137	1100	1180	1142	1100	1190
Exhaust after Turbo	977	940	1030	984	940	1130
Fuel at Filter	88	80	92	90	84	94
<u>Pressures</u>						
Compressor Discharge	7.8	7.1	8.4	10.2	9.1	11.1
Blower Discharge	9.7	9.0	10.2	15.6	15.0	16.4
Exhaust Before Turbo	7.5	7.0	7.8	11.0	10.1	11.6
Oil Consumption (lb/hr avg for 240 hr)	0.378					





LUBRICANT ANALYSIS
6V53T-CI 5136206-5
LUBRICANT: AL-6947-L
FUEL: 1-H CAT

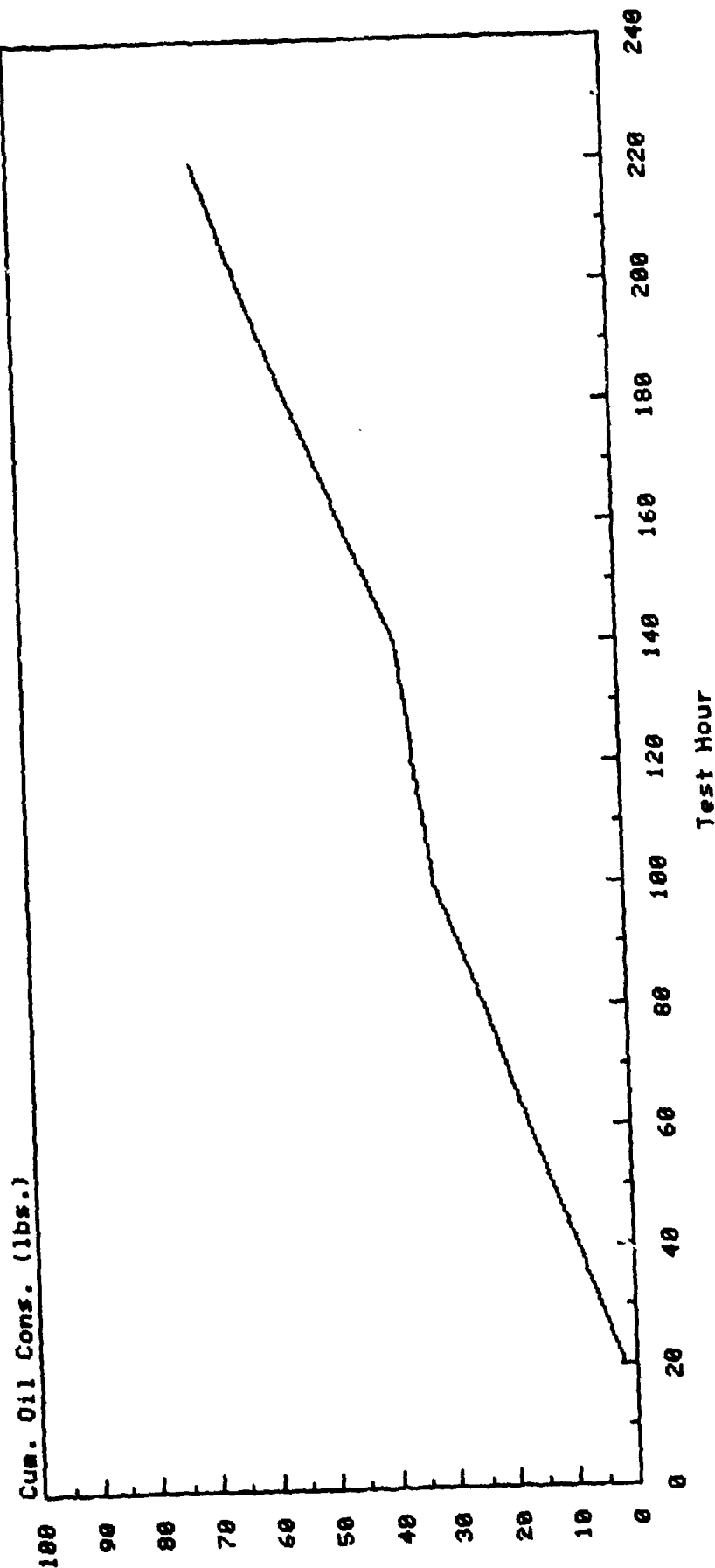
TEST HOUR

Property	ASTM Method	New	20	40	60	80	100	120	140	160	180	200	220	240
K. Vis @40°C, cSt	D 445	68.51	69.22	70.86	71.13	72.45	72.78	74.48	68.92	70.28	71.79	72.15	73.48	74.63
K. Vis @100°C, cSt	D 445	10.58	10.18	10.34	10.40	10.53	10.56	10.66	10.26	10.33	10.44	10.52	10.59	10.72
VI	D 2270	143	132	133	132	132	132	130	134	132	132	132	131	131
TAN	D 664	2.5	2.6	2.7	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.1	3.1
TEN	D 2896	8.6	8.6	8.4	8.8	8.6	8.9	8.8	8.8	8.5	7.7	8.2	8.1	8.5
Insolubles, %	D 893	0.02	-	0.049	-	0.056	-	0.086	-	0.084	-	0.099	-	0.208
Pentane B		0.02	-	0.034	-	0.051	-	0.083	-	0.073	-	0.074	-	0.146
Benzene B		-	-	0.028	-	0.050	-	0.083	-	0.070	-	0.072	-	0.147
Toluene B		228	-	-	-	-	-	240	-	-	-	-	-	246
Flash Point, °C	D 92	1.22	-	-	-	-	-	2.21	-	-	-	-	-	2.48
Carbon Residue, %	D 524	1.16	-	-	-	-	-	1.46	-	-	-	-	-	1.52
Sulfated Ash, %	D 872	29.9	-	-	-	-	-	28.7	-	-	-	-	-	28.3
Gravity, °API	D 287	-	-	-	-	-	-	-	-	-	-	-	-	-
Wear Metals by XRF														
Fe, ppm		-	85	140	199	233	237	241	219	251	249	246	250	250
Cu, ppm		-	-	35	28	22	26	20	10	-	-	-	-	-

- = Not determined

6V53T ENDURANCE TEST - 240 Hr. TRACKED

Test No. C15136206-5 Oil: AL-6947-L



WEAR MEASUREMENTS
TEST NO.: CI 5136206-5
OIL: AL-6947-L
TEST HOURS: 240

Cylinder No.		Cylinder Liner I.D.					
		Perpendicular to Crankshaft			Parallel to Crankshaft		
		Top	Middle	Bottom	Top	Middle	Bottom
1L	Before	3.8756	3.8757	3.8761	3.8757	3.8758	3.8759
	After	3.8790	3.8770	3.8769	3.8755	3.8756	3.8761
	Change	0.0034	0.0013	0.0008	-0.0002	-0.0002	0.0002
2L	Before	3.8755	3.8756	3.8760	3.8756	3.8758	3.8760
	After	3.8798	3.8775	3.8770	3.8778	3.8774	3.8774
	Change	0.0043	0.0019	0.0010	0.0022	0.0016	0.0014
3L	Before	3.8758	3.8758	3.8759	3.8755	3.8757	3.8758
	After	3.8781	3.8776	3.8778	3.8763	3.8762	3.8768
	Change	0.0023	0.0018	0.0019	0.0008	0.0005	0.0010
1R	Before	3.8755	3.8756	3.8758	3.8754	3.8756	3.8759
	After	3.8798	3.8788	3.8774	3.8784	3.8776	3.8771
	Change	0.0043	0.0032	0.0016	0.0030	0.0020	0.0012
2R	Before	3.8753	3.8756	3.8761	3.8753	3.8757	3.8758
	After	3.8762	3.8762	3.8769	3.8759	3.8760	3.8766
	Change	0.0009	0.0006	0.0008	0.0006	0.0003	0.0008
3R	Before	3.8757	3.8760	3.8762	3.8759	3.8760	3.8761
	After	3.8770	3.8768	3.8770	3.8758	3.8760	3.8766
	Change	0.0013	0.0008	0.0008	-0.0001	0.0000	0.0005

WEAR MEASUREMENTS
ENGINE NUMBER 5136206-5
OIL: AL-6947-L
TEST HOURS: 240

Piston No.		Piston Ring End Gap, inches						
		1	2	3	4	5	6	7
1L	Before	0.036	0.032	0.035	0.031	0.022	0.018	0.018
	After	0.044	0.035	0.038	0.033	0.040	0.030	0.032
	Change	0.008	0.003	0.003	0.002	0.018	0.012	0.014
2L	Before	0.033	0.032	0.027	0.025	0.021	0.018	0.018
	After	0.044	0.032	0.027	0.027	0.065	0.036	0.036
	Change	0.011	0.000	0.000	0.002	0.044	0.018	0.018
3L	Before	0.032	0.034	0.032	0.036	0.020	0.019	0.018
	After	0.035	0.036	0.036	0.042	0.038	0.030	0.032
	Change	0.003	0.002	0.004	0.006	0.018	0.011	0.014
1R	Before	0.033	0.028	0.026	0.032	0.021	0.016	0.017
	After	0.045	0.028	0.026	0.035	0.035	0.025	0.032
	Change	0.012	0.000	0.000	0.003	0.014	0.009	0.015
2R	Before	0.035	0.026	0.025	0.028	0.018	0.018	0.018
	After	0.037	0.026	0.025	0.030	0.032	0.030	0.030
	Change	0.002	0.000	0.000	0.002	0.014	0.012	0.012
3R	Before	0.027	0.033	0.031	0.035	0.021	0.018	0.018
	After	0.028	0.035	0.035	0.039	0.036	0.032	0.030
	Change	0.001	0.002	0.004	0.004	0.015	0.014	0.012
AVERAGE		0.006	0.001	0.002	0.003	0.021	0.013	0.014

RATING DATA SHEET
CI-5136206-5

Test Run at AFLRL
 Test Oil: AL-6947-L
 Test Fuel: CAT 1-H
 Test No: 5
 Test Stand: 5
 Engine No.: 6V53T 5136206
 Test Hours: 240
 Date Started: 15 April 1979
 Completed: 2 May 1979

A. Cylinder Liner Ratings

Intake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
1 L	2
2 L	2
3 L	30
1 R	1
2 R	1
3 R	5
Average	7

Scuffing, Glazing and Lacquer*

<u>Cylinder</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>Total</u>		
1 L	70	10	40	10	90
2 L	75	15	45	15	85
3 L	30	10	20	5	95
1 R	35	65	50	10	90
2 R	25	15	20	15	85
3 R	50	5	28	5	95
Average	48	20	34	10	90

*Ring Travel Area

RATING DATA SHEET - CONTINUED
CI-5136206-5

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition			
	Ring			
	Fire	No. 1	No. 2	No. 3
1 L	F x 15%B	F x 80%B	F x 80%B	F x 100%B
2 L	F x 5%B	F 65%B	F 100%B	F 75%B
3 L	F x 60%B	F 100%B	F 75%B	F 100%B
1 R	F 75%B	F 100%B	F 100%B	F 70%B
2 R	5%P 5%B	F 2%B	F 5%B	F 2%B
3 R	F 100%B	F 90%B	F 100%B	F 50%B

P=Pinched, x=Part of ring face chrome chipped.

Cylinder No.	Ring Groove Carbon Filling and Oil Groove Lacquer			
	Groove Filling, %			
	Fire	No. 1	No. 2	No. 3
1 L	10	85	60	5
2 L	5	80	30	5
3 L	5	95	30	5
1 R	10	75	30	0
2 R	5	65	10	0
3 R	10	85	15	5

Cylinder No.	Land Description
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Cylinder No.	Skirt	
	Thrust	Anti-Thrust
1 L	7.0 10% Plate melt and scuff	7.0 5% Plate melt and light scuff
2 L	7.0 5% Scuff and light scratches	7.4 5% Plate melt, 10% scuff w/lt. scratches
3 L	6.5 10% Scuff and light scratches	7.0 15% Plate melt, 1t. scratches
1 R	6.0 Light Scratches	6.3 Light scratches
2 R	6.8 Light Scratches	7.0 Light scratches
3 R	6.5 20% Plate melt, 25% scuff with scratches	6.5 5% Scuff and light scratches

RATING DATA SHEET - CONTINUED
CI-5136206-5

C. Other Ratings

Combustion Chambers

<u>Cylinder No.</u>	<u>Description</u>	<u>Cylinder No.</u>	<u>Description</u>
1 L	90% AHC	1 R	90% AHC
2 L	90% AHC	2 R	90% AHC
3 L	90% AHC	3 R	90% AHC

Valve Covers, Oil Pan and Cylinders Head Deck

Covers	Clean
Pan	Clean
Deck	Clean

Remarks

NONE

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 1-Right

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY *FRL
 LUBRICANT AL-6947-L
 RATER E. Lyons DATE 5-7-79
 LABORATORY TEST NUMBER 5136206-5
 STAND NO. 6V53T ENGINE NO. 5136206
 FUEL 1-H Cat

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME-%	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD* RATING	308.25
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC	100		10	10.00					10	10.00	50	50.00	30	30.00				
	MHC	0.75		90	67.50	25	15.00			65	32.50			30	15.00				
	MC	0.50	20	10.00						25	6.25	10	2.50	10	2.50				
	LC	0.25										40	6.00	30	4.50				
	VLC	0.15	80	12.00			75	11.25						52.00					
CARBON RATING		22.00		77.50		26.25				48.75		58.50				15	1.50	100	10.00
LACQUER	BL	0.100																	
	DBrL	0.075						100	7.50							85	4.25		
	AL	0.050																	
	LAL	0.025																	
	VLAL	0.010																	
LACQUER RATING								7.50								5.75		10.00	
CLEAN		0																	
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		22.0		77.50		26.25		7.50		48.75		58.50		52.00		5.75		10.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle RATER E. Lyons DATE 5-7-79 PISTON NO. 2 - Right

TEST HOURS 240 LABORATORY TEST NUMBER 5136206-5

TEST LABORATORY AFLRL STAND NO. 5 ENGINE NO. 6V53T 5136206

LUBRICANT AL-6947-L FUEL 1-H CAT

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME %	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD* RATING	
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC 1.00			35	35.00							75	75.00						
	MHC 0.75			45	33.75														
	MC 0.50			20	10.00				90	45.00				10	5.00				
	LC 0.25	10	2.50						10	2.50	10	2.50							
	VLC 0.15	90	13.50								15	2.25	90	13.50					
CARBON RATING		16.00		78.75					47.50		79.75		18.50						
LACQUER	BL 0.100					100	10.00									50	5.00	100	10.00
	DBrL 0.075							100	7.50							50	3.75		
	AL 0.050																		
	LAL 0.025																		
	VLAL 0.010																		
LACQUER RATING						10.00		7.50											
CLEAN 0																			
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		16.00		78.75		10.00		7.50		47.50		79.75		18.50		8.75		10.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY APLRL
 LUBRICANT AL-6947-L

RATER E. Lyons DATE 5-7-79
 LABORATORY TEST NUMBER 5136206-5
 STAND NO. 5 ENGINE NO. 5136206
 FUEL 1-H CAT

PISTON NO. 3-Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME-%	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC	1.00	90	90.00								85	85.00						
	MHC	0.75																	
	MC	0.50	10	5.00						90	45.00								
	LC	0.25						65	16.25	10	2.50			100	2.50				
	VLC	0.15	100	15.00				35	5.25			15	2.25						
LACQUER	CARBON RATING		15.00	95.00				21.50		47.50	87.25	2.50							
	BL	0.100							100	10.00							100	10.00	10.00
	DBrL	0.075																	
	AL	0.050																	
	LAL	0.025																	
CLEAN	VIAL	0.010																	
	RL	0.001																	
	LACQUER RATING								10.00								10.00	10.00	
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		15.00	95.00	21.50	10.00	47.50	87.25	2.50	10.00									10.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 1-Left

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-6947-L

RATER E. Lyons DATE 5-7-79
 LABORATORY TEST NUMBER 5136206-5
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

NO. 1 GROOVE, VOLUME %
 PISTON WTD* RATING 382.75

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN		
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4				
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%
CARBON	HC	1.00																			
	MHC	0.75		100	75.00	25	18.75														
	MC	0.50				10	5.00														
	LC	0.25					65	17.25													
	VLC	0.15	100	15.00																	
		CARBON RATING	15.00		75.00		41.00				50.00		81.25		82.50		18.00				
		BL	0.100							100	10.00										
		DBrL	0.075																		
		AL	0.050																		
		LAL	0.025																		
		VLAL	0.010																		
		RL	0.001																		10.00
		LACQUER RATING							10.00												
		CLEAN	0																		
		ZONAL RATING																			
		LOCATION FACTOR									50.00		81.25		82.50		18.00				10.00
		WEIGHTED RATING	15.00		75.00		41.00		10.00												

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-6047-L

RATER E. Lyons DATE 5-7-79
 LABORATORY TEST NUMBER 5136206-5
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

PISTON NO. 2-Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES										LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	PISTON WTD* RATING	324.00
CARBON	HC 1.00	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
	MHC 0.75	10	10.00			80	60.00	65	65.00								
	MC 0.50	70	52.50														
	LC 0.25	20	5.00	25	12.50	20	5.00	10	2.50	40	20.00	20	10.00				
	VLC 0.15	100	15.00	45	11.25			25	3.75	60	15.00	80	12.00				
CARBON RATING		15.00	67.50	30	4.50	65.00	71.25	35.00	22.00								
LACQUER	BL 0.100			28.25												100	10.00
	DBrL 0.075																
	AL 0.050																
	LAL 0.025																
	VLAL 0.010																
LACQUER RATING																	
CLEAN 0																	
ZONAL RATING																	
LOCATION FACTOR																	
WEIGHTED RATING		15.00	67.50	28.25	10.00	65.00	71.25	35.00	22.00								

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 3-Left

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-6947-I

RATER E. Lyons DATE 5-7-79
 LABORATORY TEST NUMBER 5136206-5
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1 GROOVE, VOLUME-%	PISTON WTD * RATING
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC 1.00			60	60.00							75	75.00						
	MHC 0.75			20	15.00														
	MC 0.50			20	10.00	25	12.50			70	35.00	10	5.00	15	7.50				
	LC 0.25					75	18.75			20	5.00			85	21.25				
	VLC 0.15	100	15.00							10	1.50	15	2.25			30	4.50		
LACQUER	CARBON RATING																		
	BL 0.100																		
	DBrL 0.075																		
	AL 0.050																		
	LAL 0.025																		
CLEAN	VLAL 0.010																		
	RL 0.001																		
	LACQUER RATING																		
	CLEAN 0																		
	ZONAL RATING																		
LOCATION FACTOR																			
WEIGHTED RATING																			
TOTAL DEPOSITS																			

*WEIGHTED TOTAL DEPOSITS

RING STICKING

Test No. CI-5

Engine Model 6V53T Serial No. 5136206 Date 5-7-79
 Fuel 1-H CAT Lubricant AL-6947-L Observer E. Lyons

Ring No.	Piston Number					
	1L	2L	3L	1R	2R	3R
1	F	F	F	F	5% Pinched	F
2	F	F	F	F	F	F
3	F	F	F	F	F	F
4	F	F	F	F	F	F

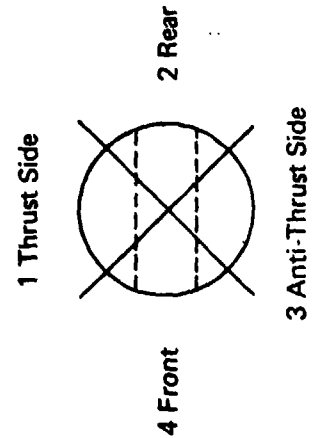
Indicate by letter — Free or Sluggish, or by number and letter — percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

PISTON GROOVE INSIDE DIAMETER - % RING SUPPORTING CARBON

Test No. CI-5

Engine Model 6V53T Serial No. 5136206 Date 5-7-79
 Fuel 1-H CAT Lubricant AL-6947-L Observer E. Lyons

Piston Ring	Quadrant	Piston Number							
		1L	2L	3L	1R	2R	3R		
1	1	0	0	0	0	0	0		
	2	0	0	0	0	0	0		
	3	0	0	0	0	0	0		
	4	0	0	0	0	0	0		
2	1	0	0	15	0	60	95		
	2	0	0	5	20	5	95		
	3	20	0	50	20	50	100		
	4	85	40	90	0	20	95		



VALVE DEPOSITS

Test No. CI-5

Serial No. 5136206

Date 5-7-79

Engine Model 6V53T

Lubricant AL-6947-L

Observer E Lyons

Fuel 1-H CAT

Observer E Lyons

Cylinder Number													
	INT	1L			2L			3L			1R		
		CARB	LACO		CARB	LACO		CARB	LACO		CARB	LACO	
Head*	EXH	90% AHC			10% Soot						40% AHC		
Face	INT												
	EXH	100% #9 LACQUER						LIGHT CARBON					
Tulipt	INT	100% AHC											
	EXH												
Stem	INT	#9 LACQUER											
	EXH												

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S, (Page 5).

Lacquer: Pages 4, 36 and 37.

EXHAUST VALVE SURFACE CONDITIONS

Engine Model 6V53T Test No. CI-5 Date 5-7-79
 Serial No. 5136206
 Fuel I-H CAT Lubricant AL-6947-L Observer E. Lyons

	1L	2L	3L	1R	2R	3R
Freeness in Guide	F	F	F	F	F	F
Head	N	N	N	N	N	N
Face	N	Light Leaking	Leaking	Leaking	Light Leaking	Leaking
Seat	N	N	N	N	N	N
Stem	N	N	N	N	N	N
Tip	X	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

X= The tip on the first valve on the camside is worn; also one of the keepers was worn enough to almost be out of position.

TAPPETS, CAMS, AND ROCKER ARMS

Engine Model 6V53T Test No. CI-5 Date 5-7-79
 Fuel 1-H CAT Serial No. 5136206 Observer E. Lyons
 Lubricant AL-6947-L

		Cylinder Number					
		1L	2L	3L	1R	2R	3R
Tappet Deposit	INT						
	EXH	C L B A N					
	INJ						
	INT						
Tappet Surface Condition		EXH	N O R M A L	L I G H T	W E A R		
Cam Lobes		N	N	N	N	N	N
Rocker Arms	Tip	INT					
		EXH	N	N	N	N	N
	Bushing	INT					
		EXH	N	N	N	N	N
	Shaft	INT					
		EXH	N	N	N	N	N

Lacquer: Pages 4, 36 and 37 of Manual.
 See Pages 1, 2, 16 through 23, and 54 through 65.

SURFACE CONDITION

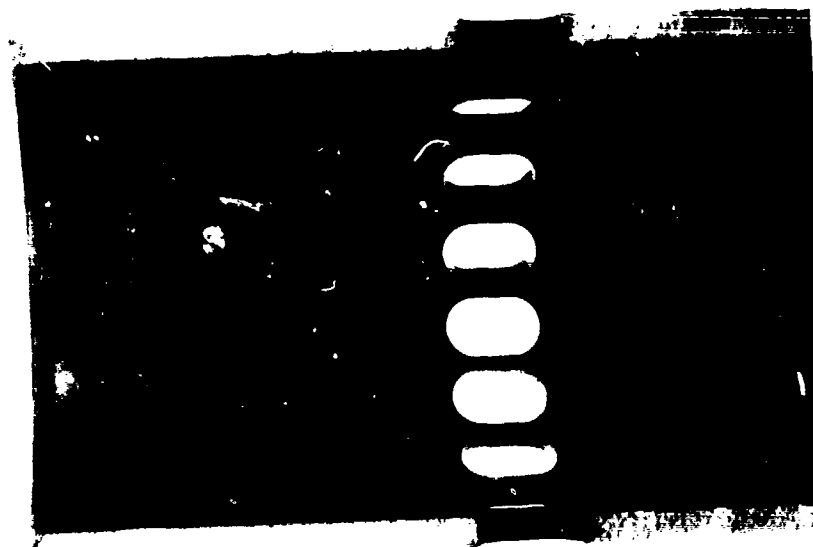
Engine Model 6V53T Test No. CI-5 Date 5-7-79
 Fuel 1-H CAT Serial No. 5136206 Observer E. Lyons
 Lubricant AL-6947-L

Bearing No.	L1	L2	L3	R1	R2	R3
Main-Bearing	Flaking & Scratched	Flaking & Scratched	Flaking & Scratched	Pitting & Scratched	X	X
	N	N	Flaking & Scratched Copper showing		X	X
Rod-Bearing	Light Scratches	Light Scratches & Pitting	Light Scratches	Light Scratches	Light Scratches	Light Scratches
	N	N	N	N	N	N
Piston Pin	N	N	N	N	N	N
	N	N	N	N	N	N

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



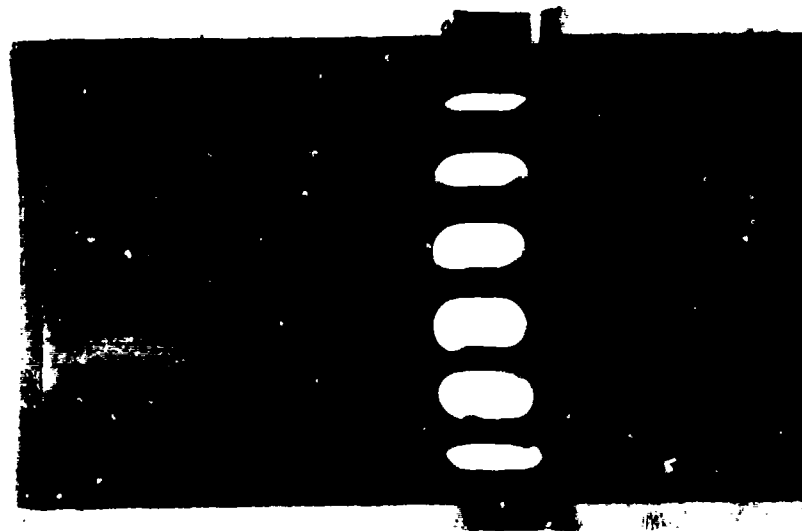
1-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

LUBRICANT: AL-6947-L



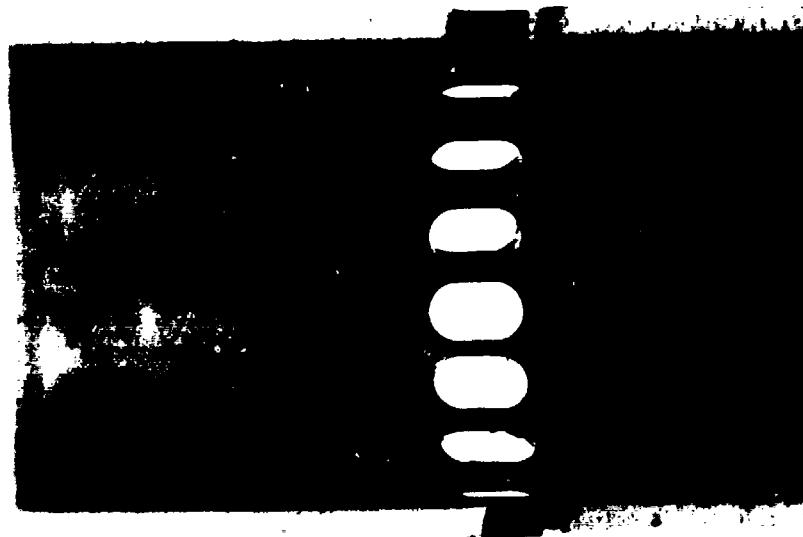
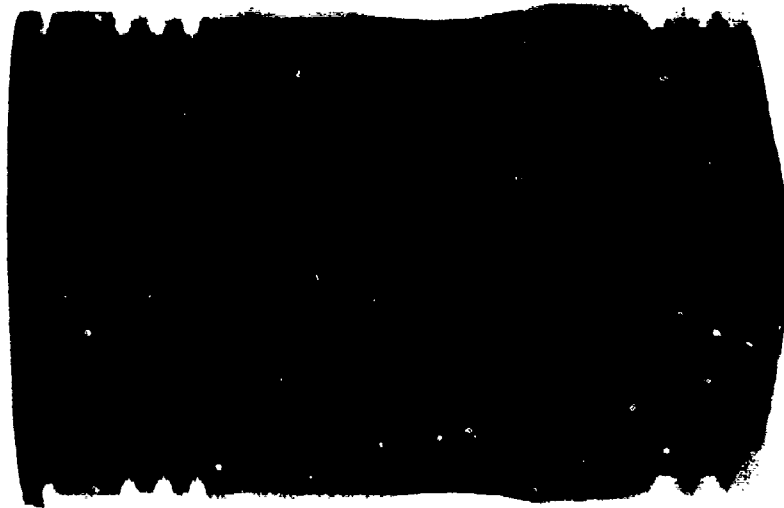
1-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

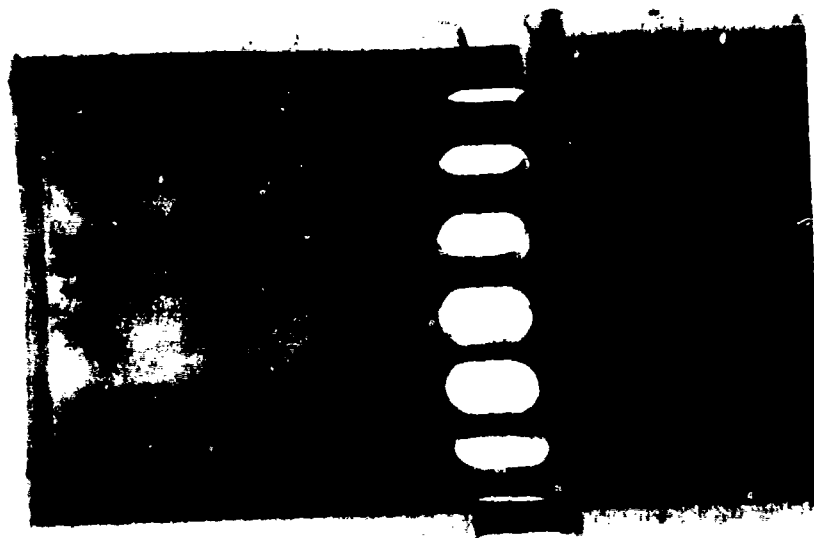
LUBRICANT: AL-6947-L



2-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

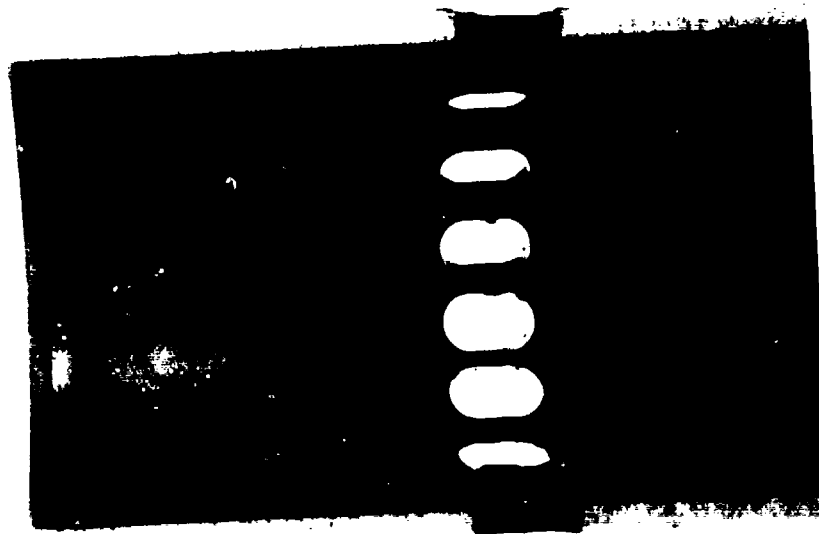
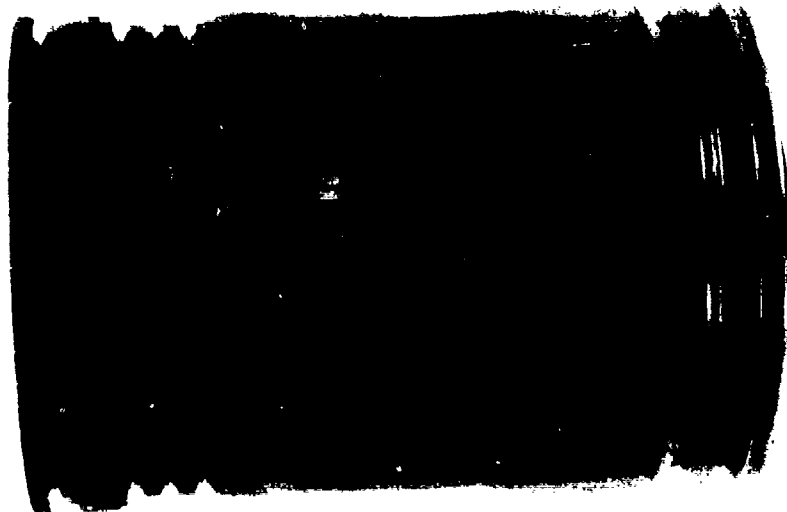
TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



2-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS · TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



3-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

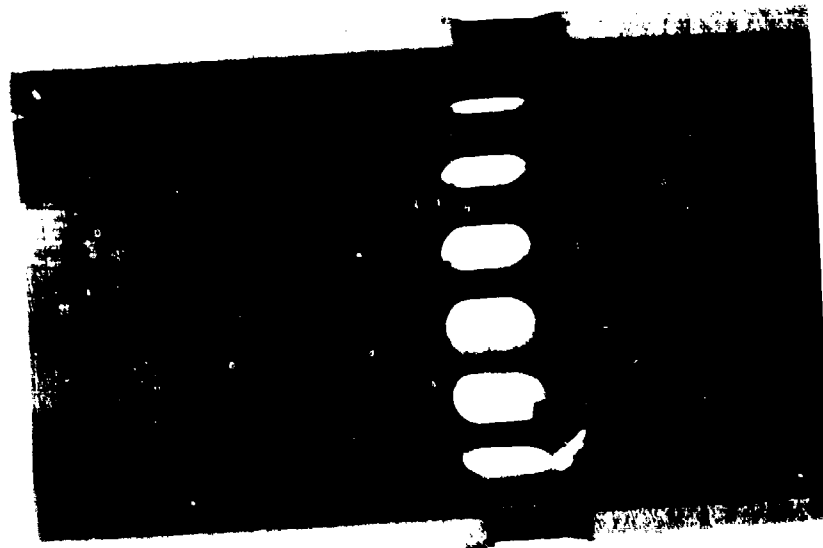
LUBRICANT: AL-6947-L



3-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



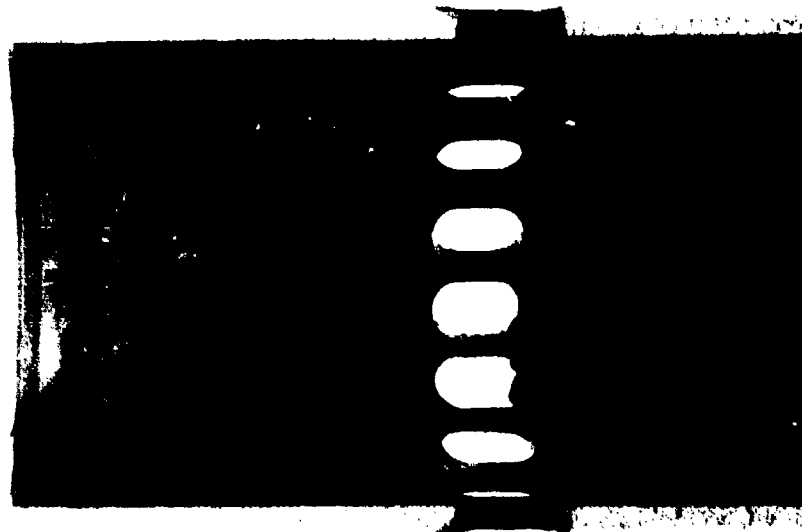
1-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

LUBRICANT: AL-6947-L



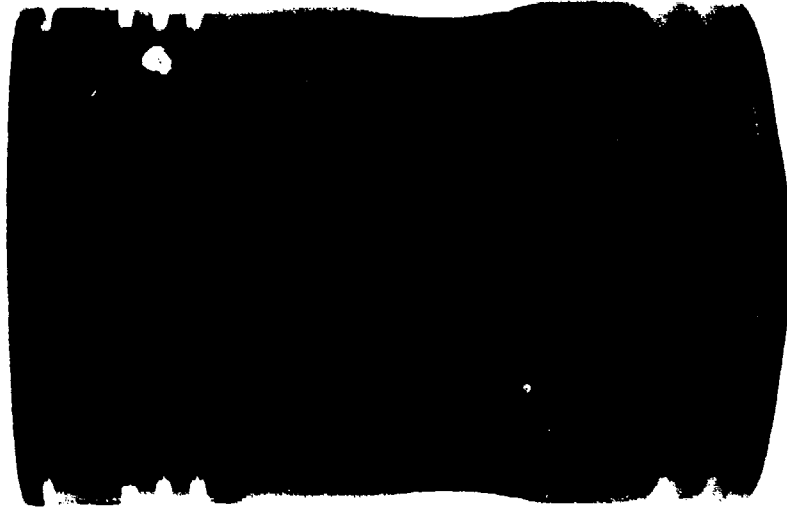
1-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

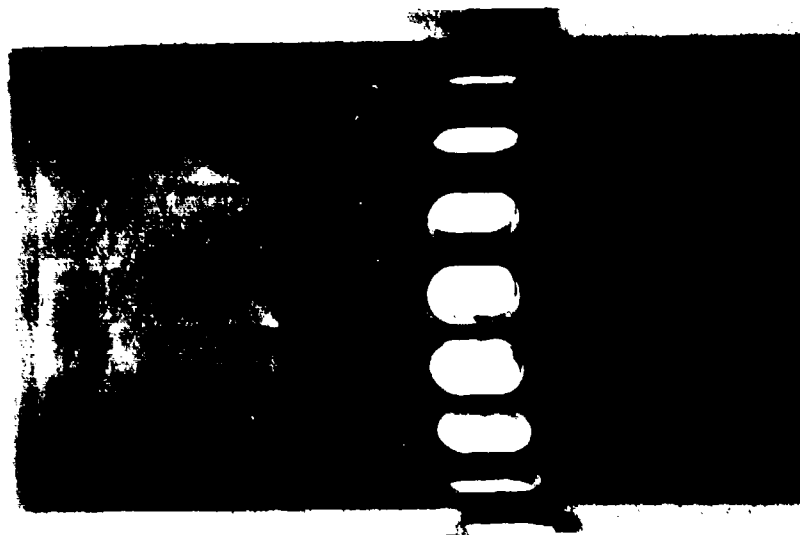
LUBRICANT: AL-6947-L



2-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



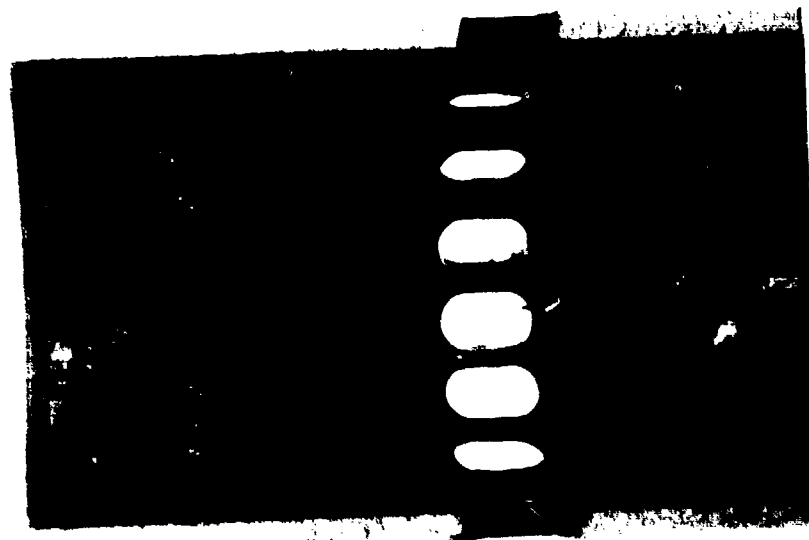
2-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L

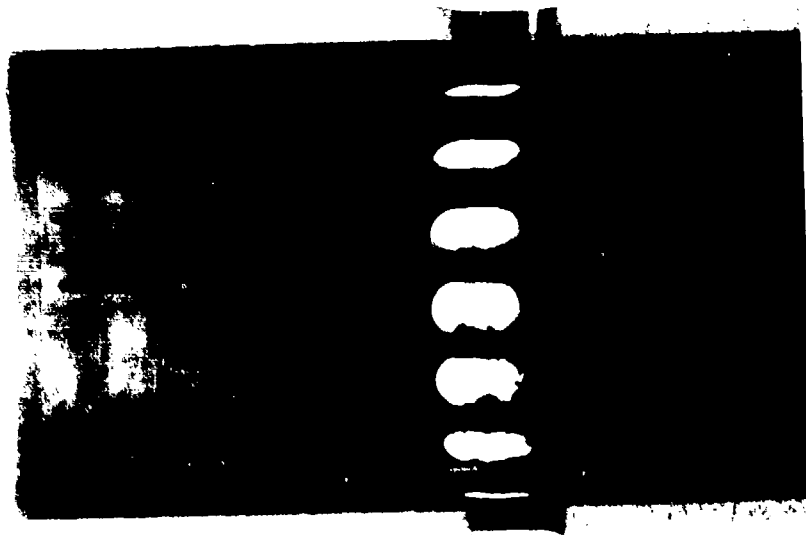


3-LEFT THRUST



CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



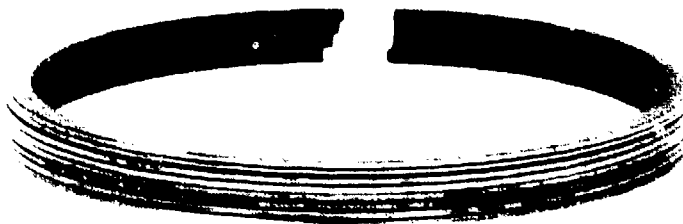
3-LEFT ANTI-THRUST

CONDITION OF PISTON RING FACE

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

LUBRICANT: AL-6947-L



1-RIGHT



2-RIGHT



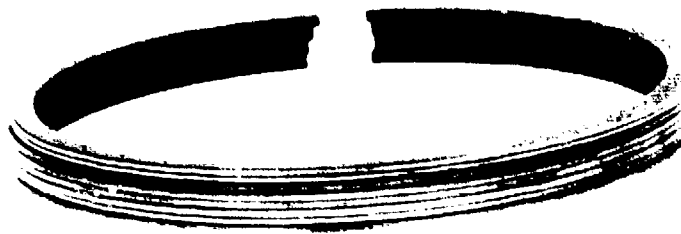
3-RIGHT

CONDITION OF PISTON RING FACE

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

LUBRICANT: AL-6947-L



1-LEFT



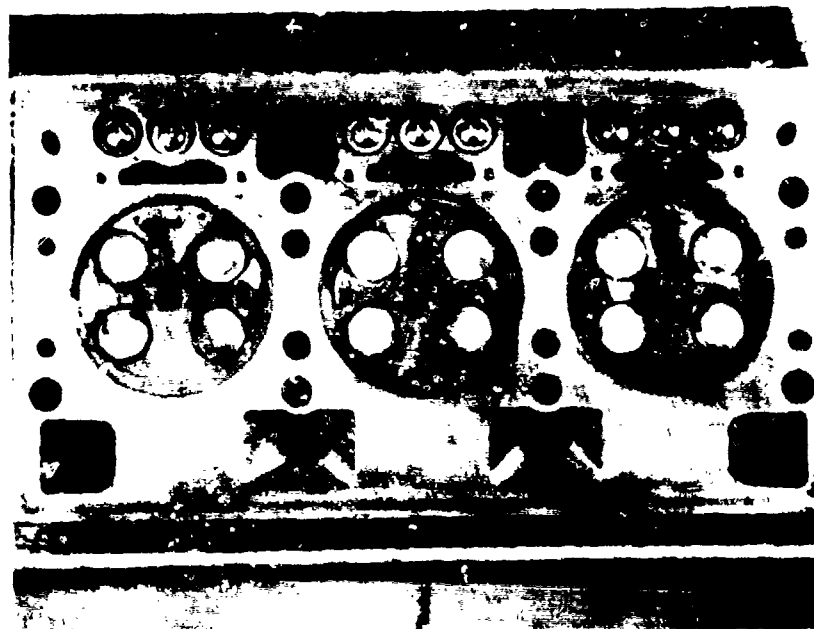
2-LEFT



3-LEFT

CONDITION OF CYLINDER HEADS

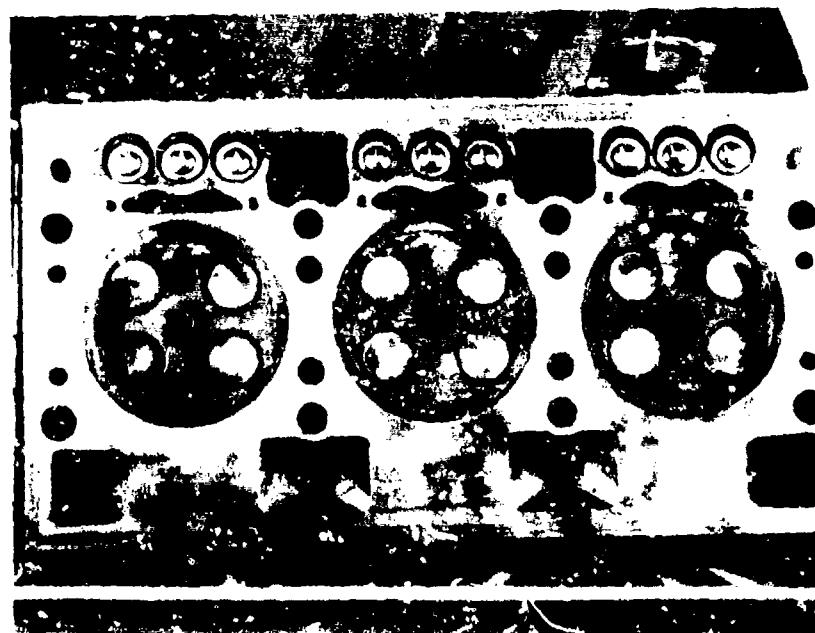
TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



3L

2L

1L



1R

2R

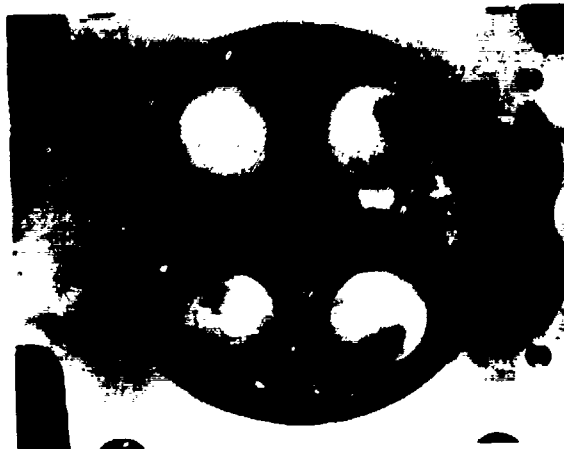
3R

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

LUBRICANT: AL-8947-L



1-RIGHT



2-RIGHT



3-RIGHT

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

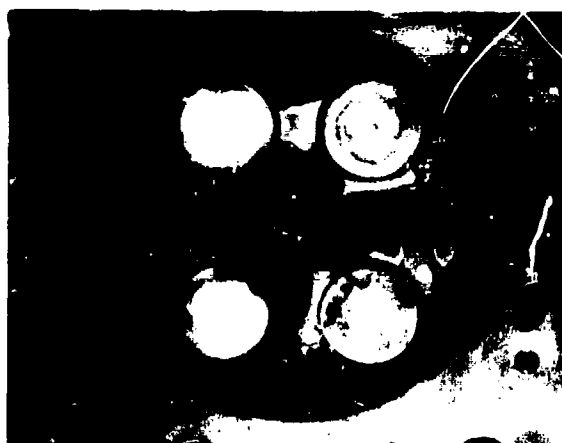
LUBRICANT: AL-6947-L



1-LEFT



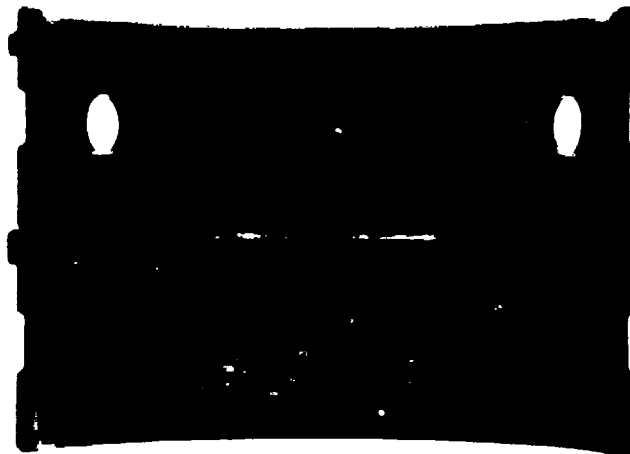
2-LEFT



3-LEFT

CONDITION OF ROD BEARINGS

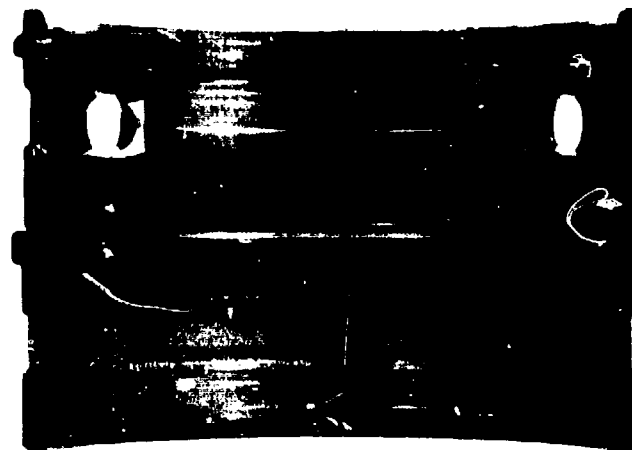
TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



1-RIGHT



2-RIGHT



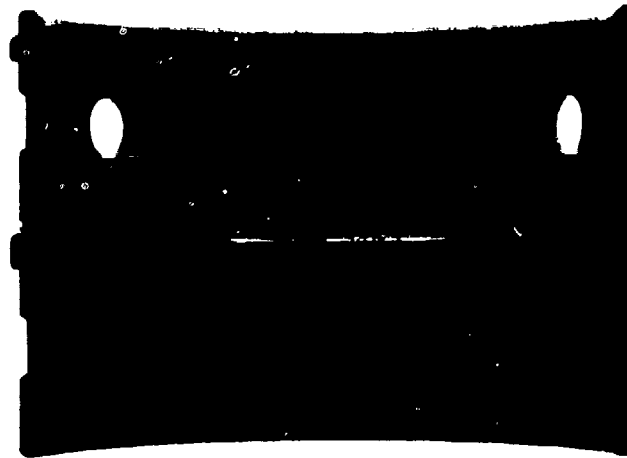
3 RIGHT

CONDITION OF ROD BEARINGS

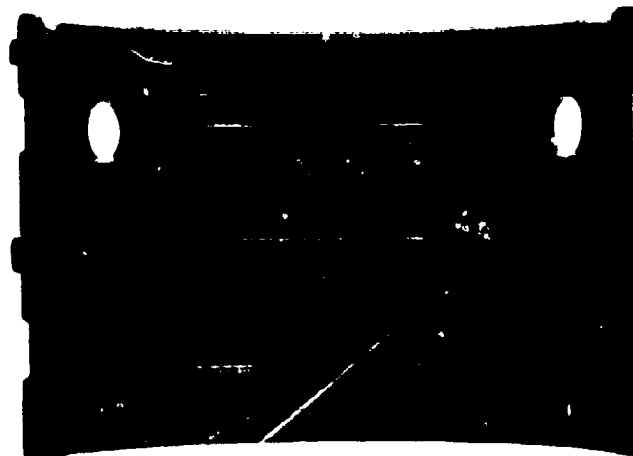
TEST TIME: 240 HOURS

TEST NO.: C15136206-5

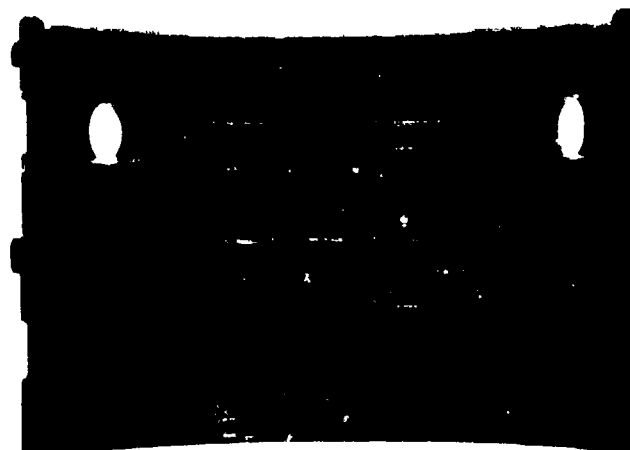
LUBRICANT: AL-6947-L



1-LEFT



2-LEFT



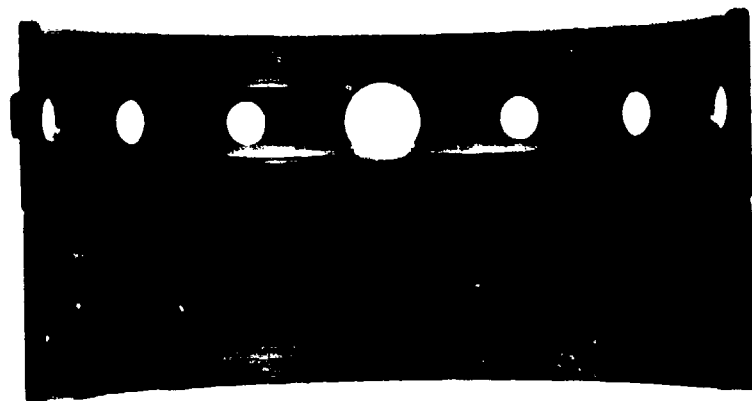
3-LEFT

CONDITION OF MAIN BEARINGS

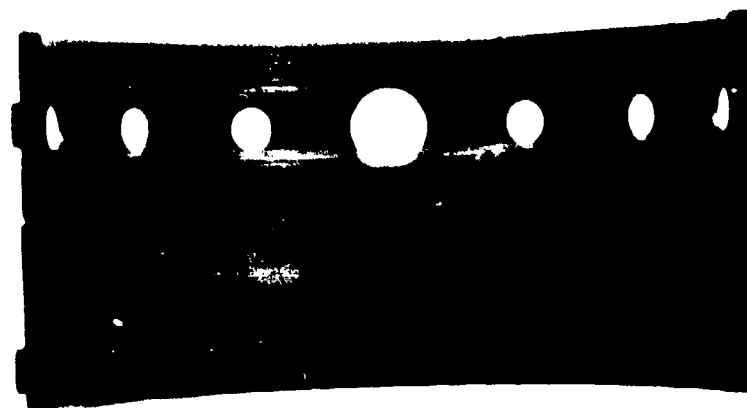
TEST TIME: 240 HOURS

TEST NO.: CI5136206-5

LUBRICANT: AL-6947-L



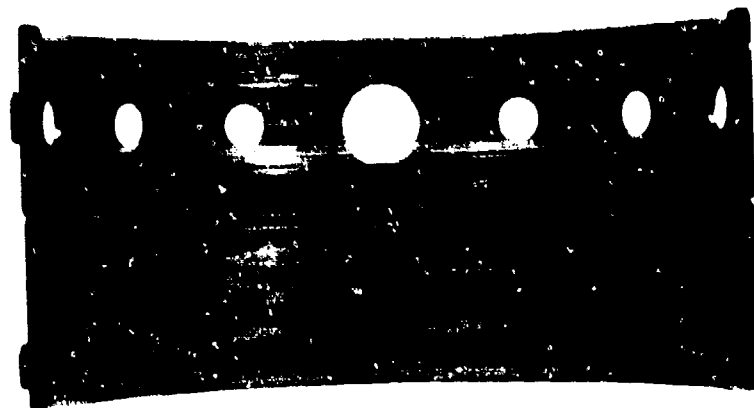
NO. 1



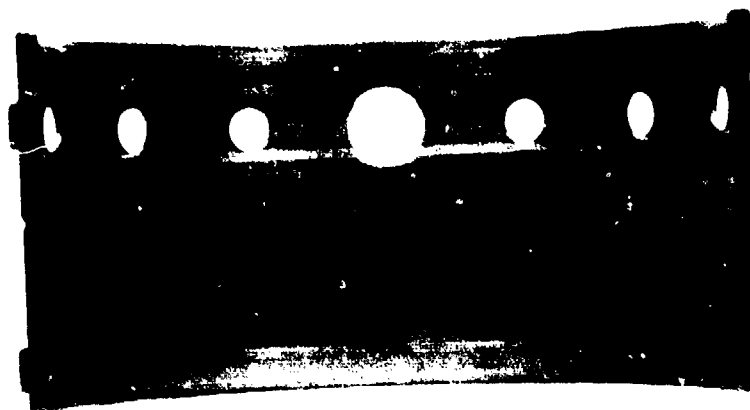
NO. 2

CONDITION OF MAIN BEARINGS

TEST TIME: 240 HOURS TEST NO.: CI5136206-5 LUBRICANT: AL-6947-L



NO. 3



NO. 4

APPENDIX D

ENGINE-LUBRICANT COMPATIBILITY TEST #6

240-HOUR TRACKED-VEHICLE CYCLE

USING 6V-53T DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V53T DIESEL ENGINE

Test Lubricant: AL-7235-8531-L
Engine Test Number: CI 5136206-6
Date Completed: 30 July 1979

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

By

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V53T
BUILD-UP ENGINE MEASUREMENTS
CI 5136206-6

Measurements	Inches			
	Min	Max	Avg	Spec Limits (1)
Crankshaft main bearing clearance	0.0040	0.0040	0.0040	0.0016-0.0046
Camshaft bearing clearance				
Left cam	0.0050	0.0051	0.0050	0.0080 max.
Right cam	0.0045	0.0047	0.0046	0.0080 max.
Connecting rod bearing clearance	0.0026	0.0031	0.0029	0.0016-0.0046
Crankshaft end-play	-	-	0.005	0.004 -0.011
Oil pump				
Between rotors	-	-	0.0070	0.004 -0.011
Outer rotor/housing	-	-	0.0030	0.001 -0.0035
Cylinder liner block bore				
Taper	0.0000	0.0002	0.0001	0.0015 max
Out-of-round	0.0000	0.0004	0.0002	0.0015 max
Inside diameter	4.3573	4.3577	4.3576	4.3595 max
Cylinder Liners(installed)				
Taper	0.0000	0.0008	0.0005	0.0020 max (2)
Out-of-round	0.0000	0.0004	0.0002	0.0030 max (2)
Inside diameter	3.8750	3.8761	3.8757	3.8752-3.8767
Piston to liner fit	0.0071	0.0087	0.0081	0.0061-0.0095
Piston diameter	3.8672	3.8682	3.8676	3.8669-3.8691
Fire ring				
End gap	0.028	0.035	0.032	0.020 -0.046
Side clearance	0.003	0.003	0.003	0.003 -0.006
No. 1 compression ring				
End gap	0.023	0.028	0.025	0.020 -0.046
Side clearance	0.005	0.008	0.006	0.007 -0.010
No. 2 & No. 3 compression ring				
End gap	0.020	0.028	0.024	0.020 -0.046
Side clearance	0.003	0.006	0.005	0.005 -0.010
Oil rings				
End gap	0.011	0.020	0.013	0.010 -0.025
Side clearance	0.002	0.005	0.003	0.0015-0.0055

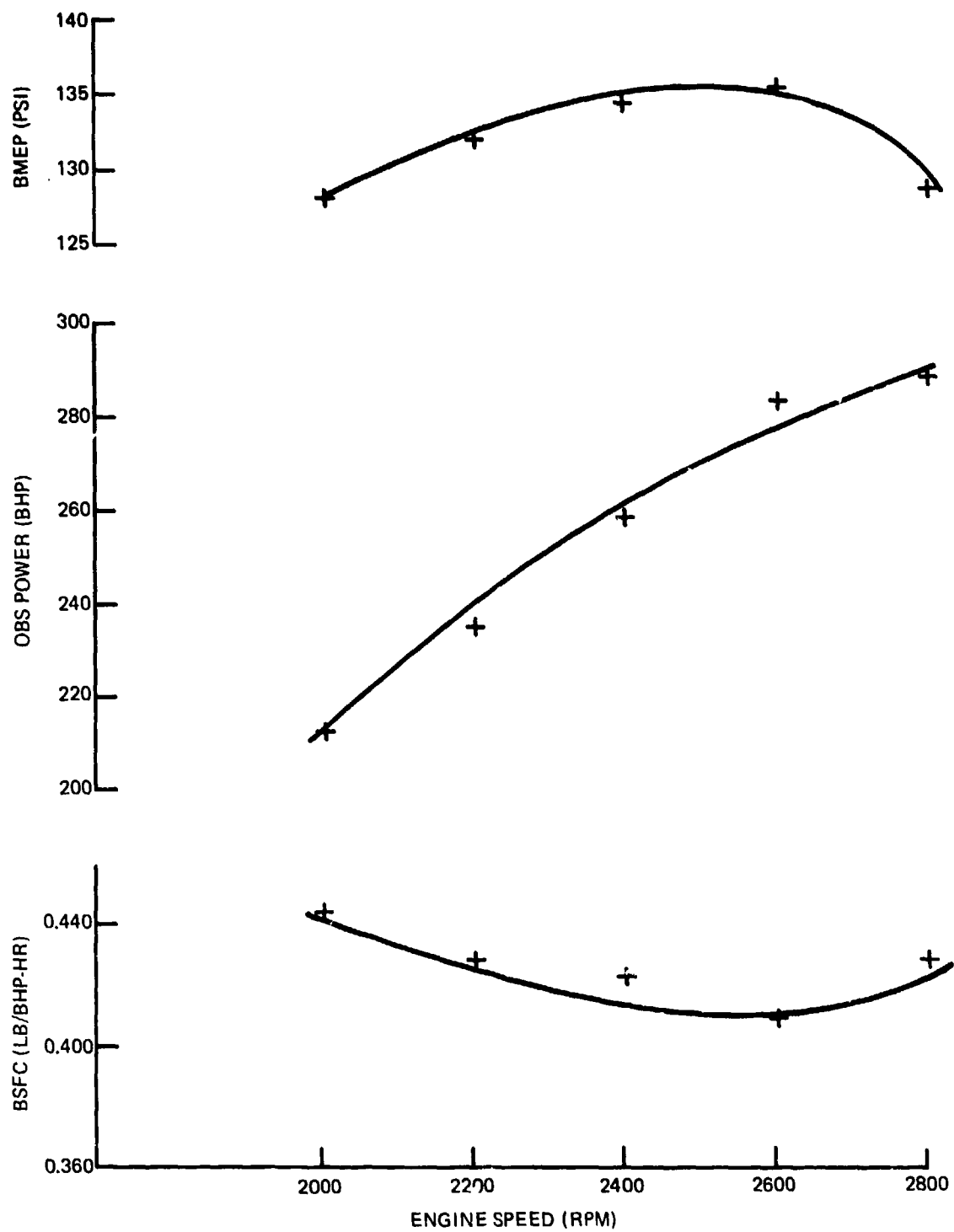
(1)Limits on new parts unless maximum wear limit specified.

(2)Wear limits with new liners in a used block.

6V53T FULL LOAD PERFORMANCE
BEFORE TEST

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



6V53T ENDURANCE TEST
SUMMARY OF OPERATING DATA

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L

	2200 RPM			2800 RPM		
	Avg	Min	Max	Avg	Min	Max
Engine Speed, rpm	2206	2185	2275	2804	2796	2812
Load, lb	454	440	468	427	415	439
Obs Power, bhp	244	234	260	292	283	301
Fuel Rate, lb/hr	100.6	99.6	101.6	121.3	119.4	123.2
BSFC, lb/bhp-hr	0.412	0.391	0.426	0.415	0.409	0.422

Temperatures, °F

Jacket In	150	140	160	146	139	153
Jacket Out	162	154	170	156	150	162
Oil Sump	246	242	250	250	246	254
Inlet Air	97	90	104	97	90	104
(Compressor)						
Airbox	242	230	254	285	267	303
Exhaust Before Turbo	1127	1090	1164	1117	1087	1143
Exhaust After Turbo	946	919	973	953	933	981
Fuel at Filter	90	88	92	93	88	98

Pressures, psi

Compressor Discharge	8.4	7.9	8.9	11.5	10.9	12.1
Blower Discharge	10.5	9.5	11.5	16.9	16.2	17.6
Exhaust Before Turbo	8.8	8.4	9.2	12.7	12.1	13.3

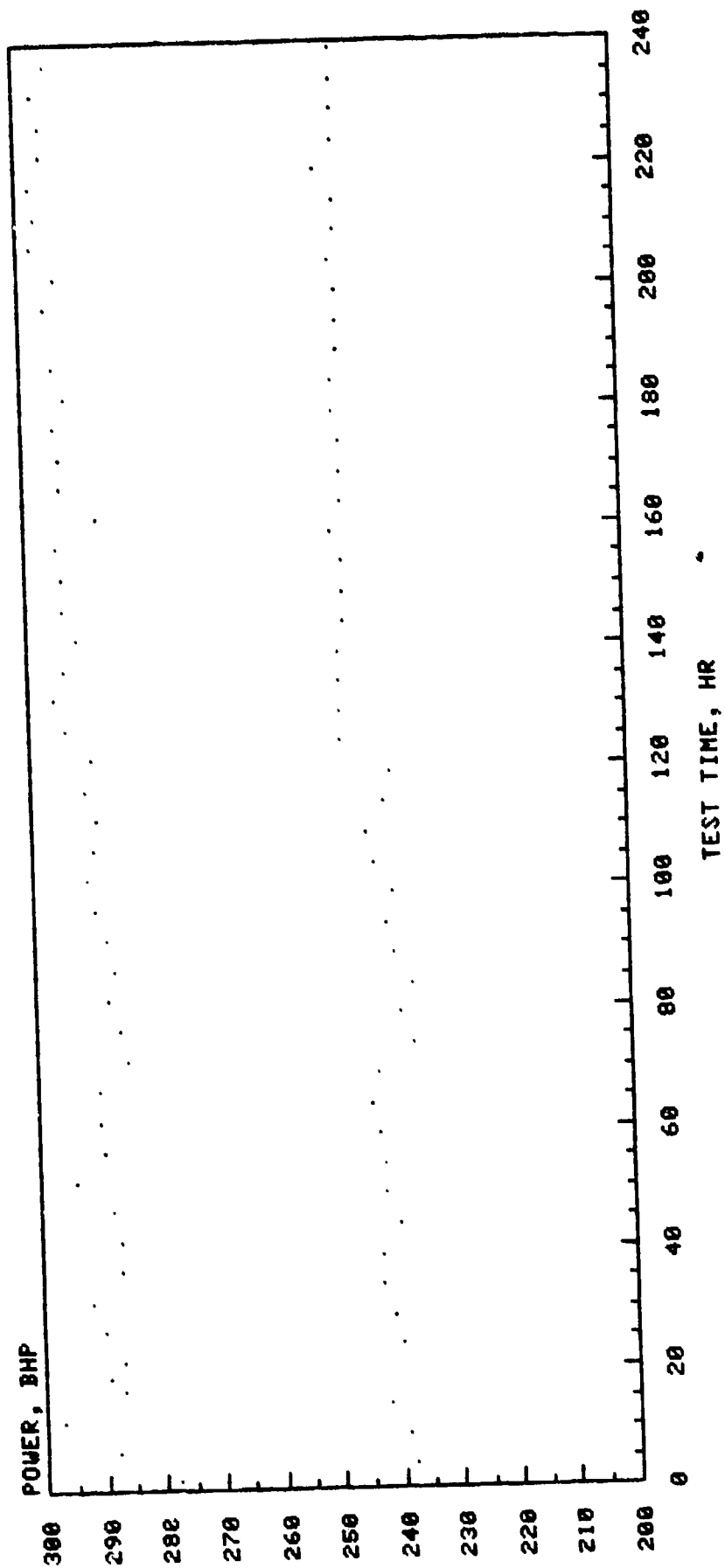
Oil Consumption

(lb/hr avg for
240 hr)

0.682

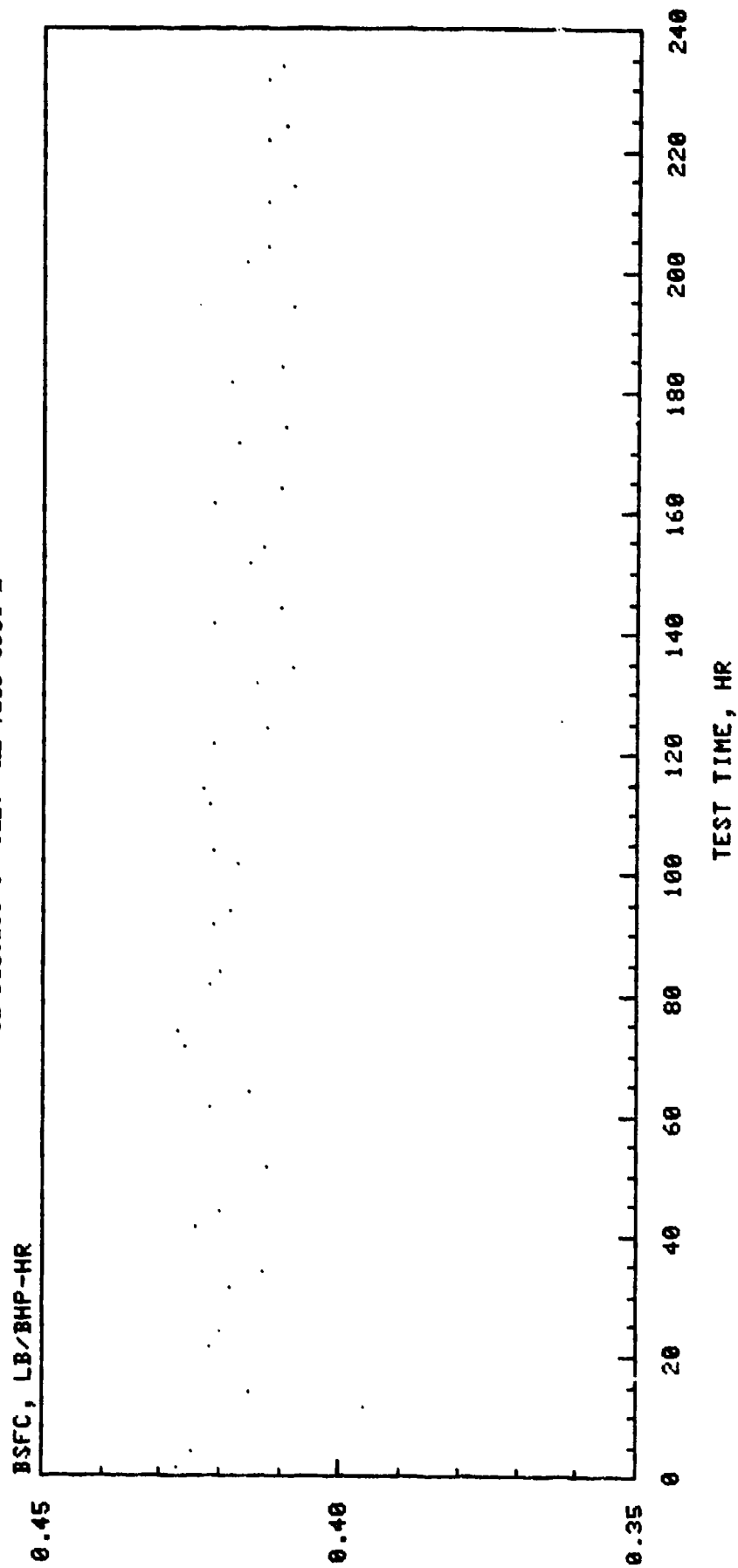
6V53T ENDURANCE TEST - 240 HR TRACKED

Test No.: CI 5136206-6 041: AL-7235-8531-L



6V53T ENDURANCE TEST - 240 HR TRACKED

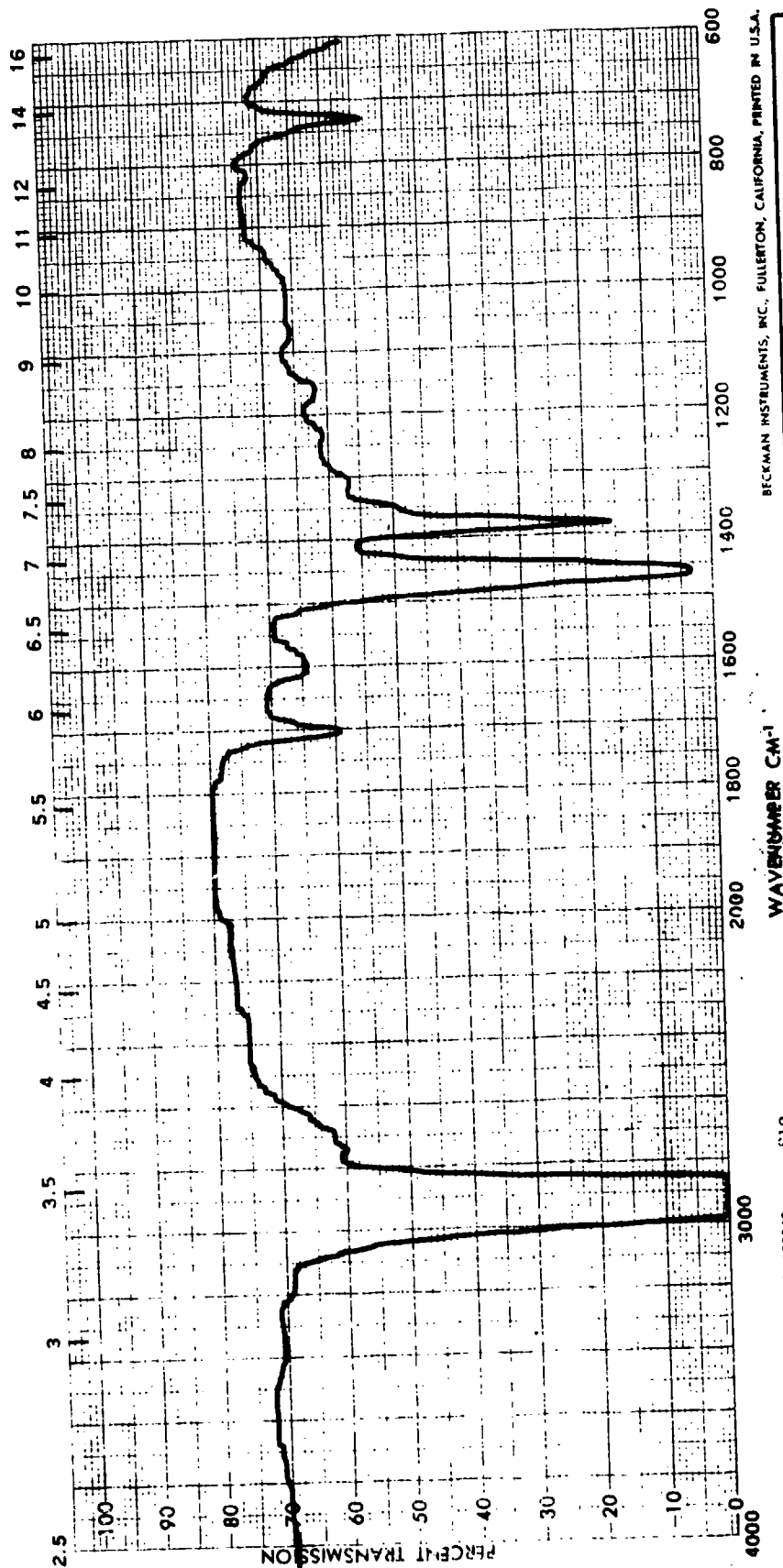
Test No.: CI 5136206-6 Oil: AL-7235-8531-L



LUBRICANT ANALYSIS
6V53T - CI5136206-6
LUBRICANT: AL-7235-8531-L
FUEL: 1-H CAT

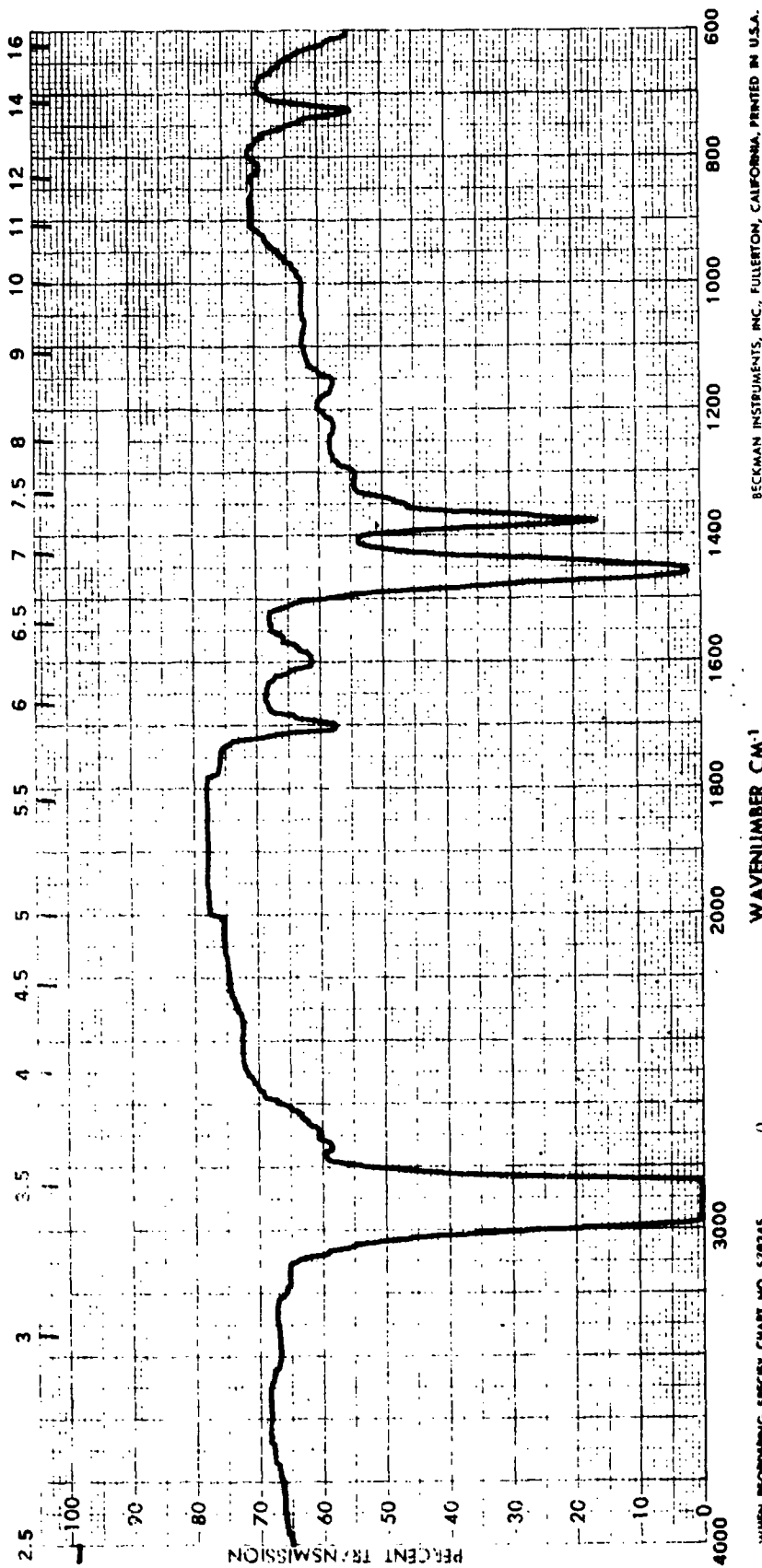
Property	ASTM Test Method	TEST HOUR												
		New	20	40	60	80	100	120	140	160	180	200	220	240
Cold Cranking Simulator @ -29°C, cP	D 2602	-						14100						14200
Cold Cranking Simulator @ -18°C, cP	D 2602	1760						2820						2900
K.Vis @40°C, cSt	D 445	66.4	66.2	68.5	69.6	72.6	70.4	71.7	65.7	66.9	68.9	69.8	70.6	70.7
K.Vis @100°C, cSt	D 445	10.5	10.0	10.2	10.3	10.6	10.4	10.6	10.0	10.1	10.2	10.3	10.4	10.4
TAN	D 664	2.1	3.05	3.93	4.15	5.10	3.55	4.60	3.50	4.28	4.10	3.25	3.35	3.40
TBN	D 664	-	5.24	5.02	4.62	4.43	4.0	3.8	4.4	4.2	4.2	4.1	4.1	4.2
TBN	D 2896	10.3			-			8.92			-			9.06
Insolubles, %														
Pentane B	D 893	0.01			0.03			0.09			0.04			0.05
Toluene B	D 893	-			0.02			0.04			0.04			0.04
Flash Point, °C	D 92	202						220						224
Pour Point, °C	D 97	-31						-29						-26
Gravity, °API @60°F	D 287	29.2						27.8						27.3
Carbon Residue, wt %	D 524	1.24						1.99						1.99
Sulfated Ash, wt %	D 874	1.09						1.37						1.34
Wear Metals by XRF														
Iron, ppm		-	66	87	93	456	244	423	93	145	186	193	191	164
Copper, ppm		-	15	25	22	65	50	42	-	-	15	20	15	20

- = Not determined



D-10

SPECTRUM NO. 1733		ORIGIN		LEGEND		REMARKS	
SAMPLE AL-7235-L				1.			
60-hr		PURITY		2.			
		PHASE		DATE 8-13-79			
		THICKNESS 0.025		OPERATOR D.B.			

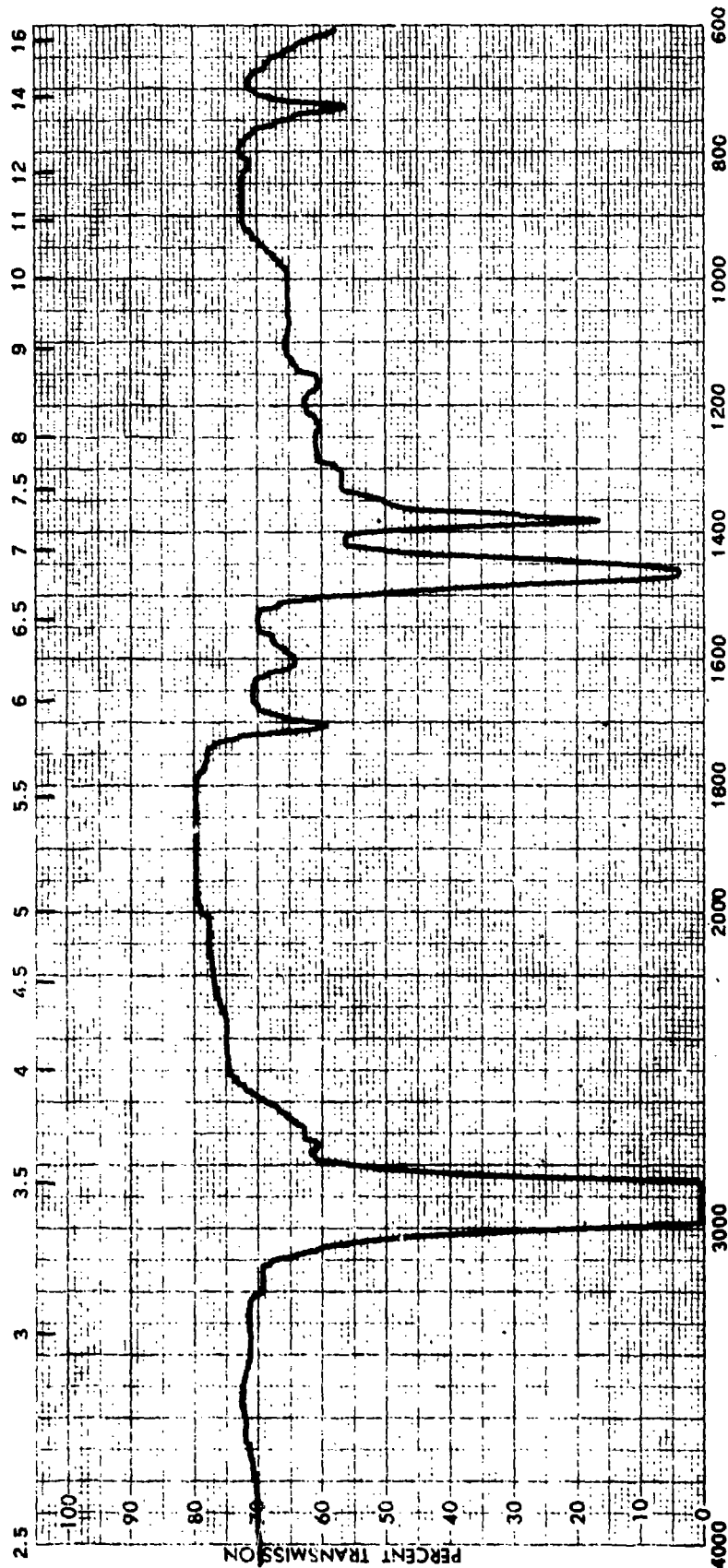


WHEN REORDERING SPECIFY CHART NO. 579345

WAVENUMBER CM⁻¹

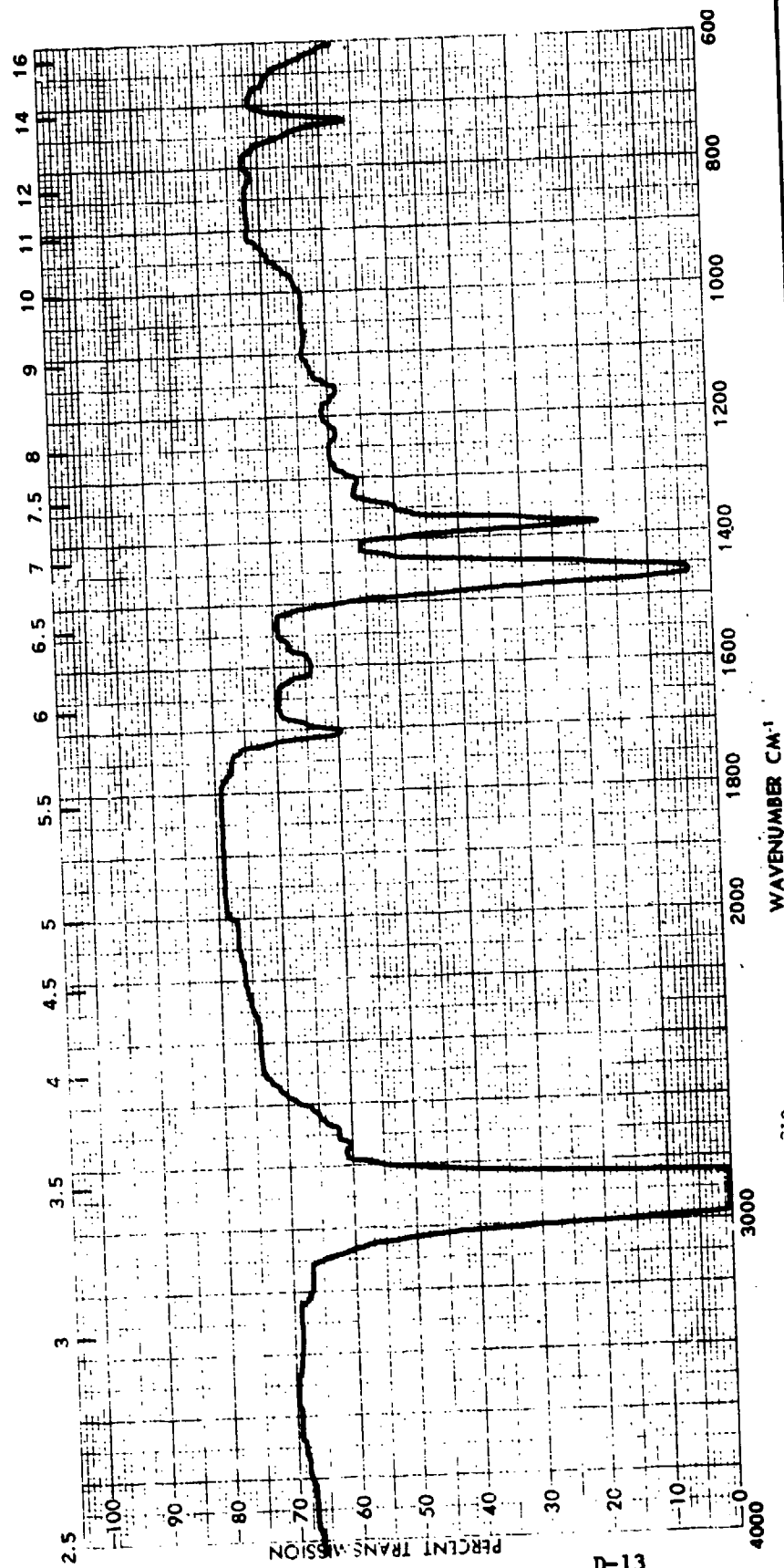
BECKMAN INSTRUMENTS, INC., FULLERTON, CALIFORNIA, PRINTED IN U.S.A.

SPECTRUM NO. <u>1734</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-7235-L</u>	_____	1. _____	_____
<u>120 hr</u>	PURITY _____	2. _____	_____
_____	PHASE _____	DATE <u>8-13-79</u>	_____
_____	THICKNESS <u>0.025</u>	OPERATOR <u>D.B.</u>	_____



WHEN RECORDING SPECIFY CHART NO. 579345 P10 BECKMAN INSTRUMENTS, INC., FULLERTON, CALIFORNIA, PRINTED IN U.S.A.

SPECTRUM NO. 1735	ORIGIN	LEGEND	REMARKS
SAMPLE AL-7235-L		1.	
180 hr	PURITY	2.	
	PHASE	DATE 8-13-79	
	THICKNESS 0.025	OPERATOR D.B.	



P-13

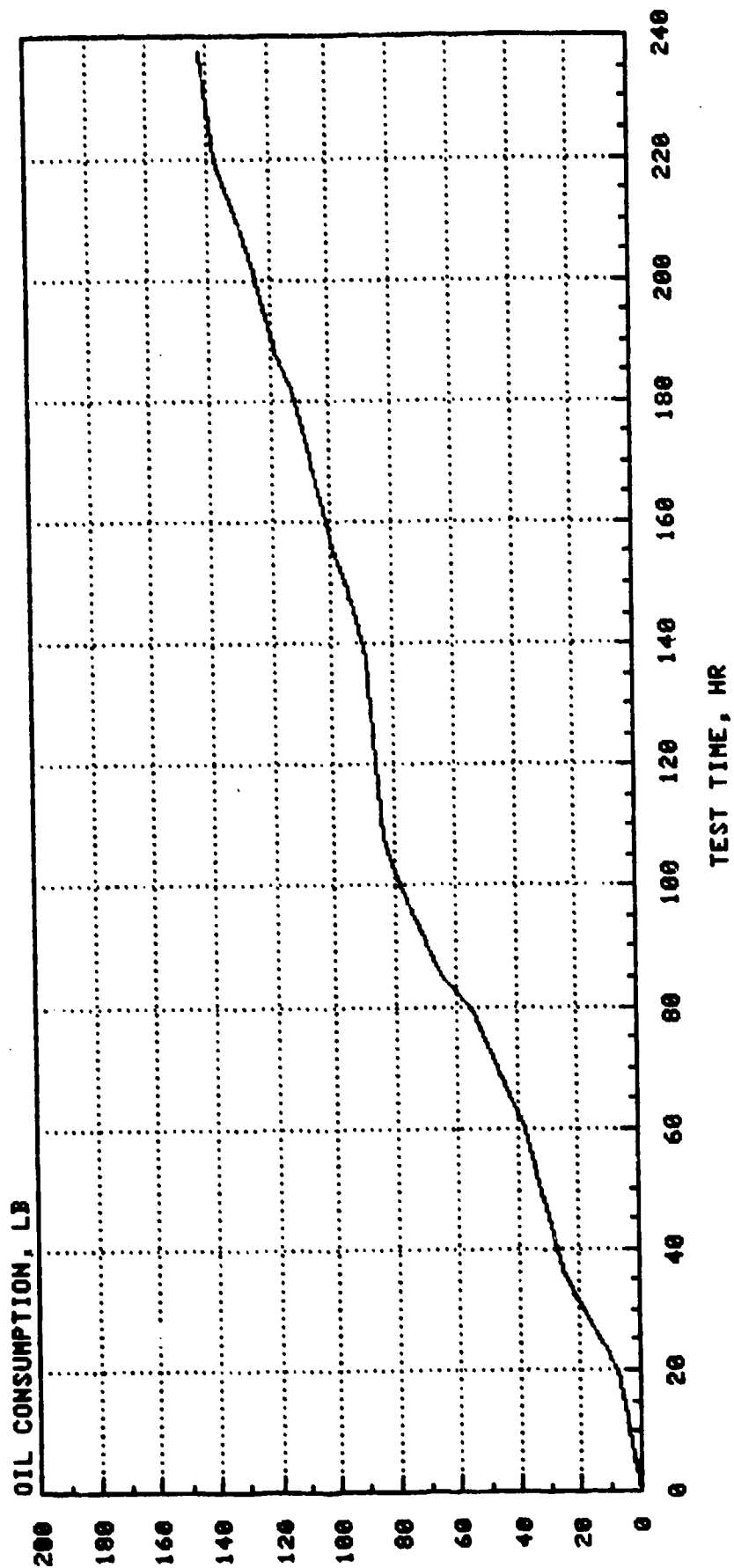
WAVENUMBER CM⁻¹

WHEN REORDERING SPECIFY CHART NO. 579345 C10

SPECTRUM NO. 1736		LEGEND		REMARKS	
SAMPLE AL-7235-L		1.			
240 hr		2.			
PURITY		DATE 8-13-79			
PHASE		OPERATOR D.B.			
THICKNESS 0.025					

6V53T ENDURANCE TEST - 240 HR TRACKED

Test No.: CI 5136206-6 Oil: AL-7235-8531-L



WEAR MEASUREMENTS
TEST NO. CI 5136206-6
LUBRICANT: AL-7235-8531-L
TEST HOURS: 240

Cylinder No.		Cylinder Liner ID					
		Perpendicular to Crankshaft			Parallel to Crankshaft		
		Top	Middle	Bottom	Top	Middle	Bottom
1L	Before	3.8753	3.8757	3.8761	3.8756	3.8756	3.8761
	After	3.8795	3.8772	3.8761	3.8767	3.8765	3.8759
	Change	0.0042	0.0015	0.0000	0.0011	0.0009	-0.0002
2L	Before	3.8755	3.8757	3.8761	3.8755	3.8756	3.8759
	After	3.8790	3.8770	3.8762	3.8779	3.8764	3.8756
	Change	0.0035	0.0013	0.0001	0.0024	0.0008	-0.0003
3L	Before	3.8758	3.8758	3.8761	3.8756	3.8758	3.8763
	After	3.8784	3.8771	3.8750	3.8766	3.8767	3.8764
	Change	0.0026	0.0013	-0.0001	0.0010	0.0009	0.0001
1R	Before	3.8750	3.8752	3.8757	3.8754	3.8755	3.8758
	After	3.8781	3.8773	3.8762	3.8787	3.8766	3.8758
	Change	0.0031	0.0021	0.0005	0.0033	0.0011	0.0000
2R	Before	3.8758	3.8755	3.8757	3.8753	3.8756	3.8759
	After	3.8745	3.8771	3.8759	3.8763	3.8767	3.8758
	Change	-0.0013	0.0016	0.0002	0.0010	0.0011	-0.0001
3R	Before	3.8753	3.8754	3.8757	3.8753	3.8755	3.8759
	After	3.8780	3.8780	3.8757	3.8716	3.8772	3.8765
	Change	0.0027	0.0026	0.0000	0.0023	0.0017	0.0006

WEAR MEASUREMENTS
ENGINE NUMBER 5136206-6
LUBRICANT: AL-7235-8531-L
TEST HOURS: 240

Piston No.	Piston Ring Gap, inches						
	1	2	3	4	5	6	7
1L Before	0.035	0.025	0.025	0.025	0.020	0.011	0.011
After	0.041	0.024	0.026	0.027	0.030	0.028	0.027
Change	0.006	-0.001	0.001	0.002	0.010	0.017	0.016
2L Before	0.028	0.023	0.023	0.021	0.020	0.011	0.011
After	0.036	0.027	0.033	0.028	0.075	0.084	0.082
Change	0.008	0.004	0.010	0.007	0.055	0.063	0.071
3L Before	0.034	0.025	0.028	0.020	0.020	0.011	0.011
After	0.039	0.029	0.029	0.024	0.033	0.024	0.025
Change	0.005	0.004	0.001	0.004	0.013	0.013	0.014
1R Before	0.031	0.020	0.020	0.030	0.015	0.012	0.011
After	0.033	0.023	0.024	0.031	0.029	0.029	0.025
Change	0.002	0.003	0.004	0.001	0.014	0.017	0.014
2R* Before	0.035	0.026	0.022	0.020	0.016	0.011	0.011
After	0.038	0.030	0.026	0.023	0.063	0.090	Broken
Change	0.003	0.004	0.004	0.003	0.047	0.079	---
2R**Before	0.042	0.031	0.040	0.035	0.022	0.019	0.019
After	0.047	0.032	0.039	0.036	0.028	0.025	0.026
Change	0.005	0.001	-0.001	0.001	0.006	0.006	0.007
3R Before	0.028	0.028	0.028	0.028	0.013	0.014	0.013
After	0.040	0.031	0.030	0.034	0.033	0.028	0.027
Change	0.012	0.003	0.002	0.006	0.020	0.014	0.014

* Failed first cylinder assembly at 120 hours.

**Second cylinder assembly.

WEAR MEASUREMENTS
ENGINE NO. 5136206-6
LUBRICANT: AL-7235-8531-L
TEST HOURS: 240

Cylinder No.	Rod Bearing Journal		Rod Bearing	
	AA	BB	F	R
1L Before	2.7495	2.7495	2.7525	2.7525
After	2.7495	2.7495	2.7521	2.7522
Change	0.0000	0.0000	-0.0004	-0.0003
2L Before	2.7493	2.7493	2.7522	2.7522
After	2.7494	2.7494	2.7525	2.7523
Change	0.0001	0.0001	0.0003	0.0001
3L Before	2.7493	2.7493	2.7524	2.7523
After	2.7493	2.7493	2.7521	2.7521
Change	0.0000	0.0000	-0.0003	-0.0002
1R Before	2.7495	2.7495	2.7521	2.7521
After	2.7494	2.7494	2.7525	2.7524
Change	-0.0001	-0.0001	0.0004	0.0003
2R Before	2.7493	2.7493	2.7524	2.7524
After	2.7493	2.7493	2.7523	2.7521
Change	0.0000	0.0000	-0.0001	0.0003
3R Before	2.7493	2.7493	2.7524	2.7524
After	2.7493	2.7494	2.7522	2.7521
Change	0.0000	0.0001	-0.0002	-0.0003

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 1-Right

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFLRL
 LUBRICANT AL-7235-8531-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

TEST LABORATORY AFRL										STAND NO. 5 ENGINE NO. 00551 215000										NO. 1 GROOVE, VOLUME-%		PISTON WTD* RATING		300.35																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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300.35

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked Cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-7235-8531-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 5136206
 FUEL 1-H CAT

PISTON NO. 2-Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME-%	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD* RATING	342.75
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC	1.00		15	15.00					95	95.00	90	90.00						
	MHC	0.75		85	63.75														
	MC	0.50																	
	LC	0.25				40	10.00	25	6.25			10	2.50	50	12.50				
	VLC	0.15	100	15.00		10	1.50			5	0.75								
CARBON RATING		15.00		78.75		11.50		6.25		95.75		92.50		12.50					
LACQUER	BL	0.100				50	5.00	75	7.50					50	5.00	10	1.00		
	DBrL	0.075																100	7.50
	AL	0.050														90	4.50		
	LAL	0.025																	
	VLAL	0.010																	
LACQUER RATING						5.00		7.50						5.00		5.50		7.50	
CLEAN D																			
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		15.00		78.75		16.50		13.75		95.75		92.50		17.50		5.50		7.50	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 85.5 Tracked Cycle
 TEST HOURS 85.5
 TEST LABORATORY AFRL
 LUBRICANT AL-7235-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

PISTON NO. 2-Right (Failed)

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME-%	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD* RATING	272.125
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC	1.00		100	100.00					90	90.00	60	60.00						
	MHC	0.75																	
	MC	0.50								10	5.00								
	LC	0.25	100	25.00		10	2.50					25	6.25	45	11.25				
	VLC	0.15										15	2.25						
CARBON RATING		25.00		100.00		2.50				95.00		14.50		11.25					
LACQUER	BL	0.100				90	9.00									5	0.50	100	10.00
	DBrL	0.075																	
	AL	0.050																	
	LAL	0.025						100	2.50					55	1.375		95	0.950	
	VIAL	0.010																	
LACQUER RATING						9.00		2.50						1.375		1.00		10.00	
CLEAN		0																	
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		25.00		100.00		11.50		2.50		95.00		14.50		12.625		1.00		10.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked Cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-7235-8531-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

PISTON NO. 3-Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES										LANDS				NO. 1 GROOVE, VOLUME-%	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	PISTON WTD* RATING	319.125
CARBON	HC	1.00															
	MHC	0.75															
	MC	0.50	100	75.00	10	7.50				100	75.00						
	LC	0.25															
	VLC	0.15															
	CARBON RATING	15.00															
LACQUER	BL	0.100															
	DBrL	0.075															
	AL	0.050															
	LAL	0.025															
	VLAL	0.010															
	RL	0.001															
LACQUER RATING																	
CLEAN		0															
ZONAL RATING																	
LOCATION FACTOR																	
WEIGHTED RATING		15.00	75.00	52.50	6.00	75.00	37.00	40.00	4.50	75.00	37.00	40.00	4.50	75.00	37.00	11.125	7.50

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked Cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-775-8531-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-B CAT

PISTON NO. 1-Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES						LANDS						UNDER-CROWN						
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1 GROOVE, VOLUME-%	PISTON WTD* RATING	345.60
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT			
CARBON	HC 1.00																			
	MHC 0.75			100	75.00															
	MC 0.50																			
	LC 0.25	55	13.75			10	2.50													
	VLC 0.15	45	6.75							10	1.50	10	1.50							
CARBON RATING		20.50		75.00		2.50				91.50		91.50		41.50						
LACQUER	BL 0.100					90	9.00													
	DBrL 0.075																			
	AL 0.050																			
	LAL 0.025							100	2.50											
	VLAL 0.010																			
LACQUER RATING						9.00		2.50						2.50		1.60		7.50		
CLEAN 0																				
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING		20.50		75.00		11.50		2.50		91.50		91.50		44.00		1.60		7.50		

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked Cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-735-8531-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 5136206
 FUEL I-H CAT

PISTON NO. 2-Left

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	271.50

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN			
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4					
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT			AREA-%	DEMERIT
CARBON	HC	1.00																				
	MHC	0.75			100	75.00																
	MC	0.50					20	10.00														
	LC	0.25																				
	VLC	0.15	100	15.00				30	4.50													
		CARBON RATING	15.00		75.00		14.50				37.50		85.00		23.00							
LACQUER	BL	0.100																				
	DBrL	0.075					50	3.75											15	1.50		
	AL	0.050							100	5.00												
	LAL	0.025																	65	3.25		
	VLAL	0.010																	20	0.50		
		RL	0.001																			
		LACQUER RATING					3.75		5.00						23.00		5.25		7.50			
		CLEAN	0																			
		ZONAL RATING																				
		LOCATION FACTOR																				
		WEIGHTED RATING	15.00		75.00		18.25		5.00		37.50		85.00		23.00		5.25		7.50			

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked Cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-7235-8531-L

RATER E. Lyons DATE 8-1-79
 LABORATORY TEST NUMBER CI 5136206-6
 STAND NO. 5 ENGINE NO. 6V53T 5136206
 FUEL 1-H CAT

PISTON NO. 3-Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME %	PISTON WTD * RATING	505.50
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4			
CARBON	HC	1.00	50	50.00						95	95.00	15	15.00							
	MHC	0.75	50	37.50												20	15.00			
	MC	0.50										75	37.50							
	LC	0.25	25	5.25		15	3.75									60	15.00			
	VLC	0.15	75	11.25						5	0.75	10	1.50							
CARBON RATING		16.50	87.50	3.75		95.75	49.00	30.00												
LACQUER	BL	0.100														10	1.00	50	5.00	
	DB/L	0.075																20	1.50	100
	AL	0.050				85	4.25											10	0.50	
	LAL	0.025							100	2.50						10	0.25	20	0.50	
	VLAL	0.010																		
LACQUER RATING						4.25	2.50									1.25	7.50			7.50
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING		16.50	37.50	8.00	2.50	95.75	49.00	31.25	7.50											7.50

*WEIGHTED TOTAL DEPOSITS

RATING DATA SHEET
CI 5136206-6

Test Run at AFRL
Test Lubricant: AL-7235-8531-L
Test Fuel: CAT 1-H
Test No.: CI 5136206-6
Test Stand: 5
Engine No.: 6V53T 5136206
Test Hours: 240
Date Started: 26 June 1979
Date Completed: 30 July 1979

A. Cylinder Liner Ratings

<u>Cylinder No.</u>		<u>Intake Port Plugging</u>	<u>Restriction, %</u>
1	L		<1
2	L		1
3	L		1
1	R		2
2	R		<1
3	R		3
Average			1

Scuffing, Glazing and Lacquer*

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>Total</u>	<u>Glazing, %</u>	<u>Lacquer, %</u>
1 L	25	5	15	5	95
2 L	30	10	20	10	90
3 L	50	10	30	10	90
1 R	10	40	25	2	98
2 R	75	5	40	2	98
3 R	30	60	70	0	100
Average	45	22	33	5	95

*Ring Travel Area

RATING DATA SHEET - CONTINUED
CI 5136206-6

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition				
	Ring				
	Fire	No.1	No.2	No.3	
1 L	5%P 1%B	F 65%B	F 80%B	F 75%B	
2 L	F 5%B	F 95%B	F 90%B	F 70%B	
3 L	F x 15%B	F 85%B	F 90%B	F 75%B	
1 R	F 15%B	F 70%B	F 85%B	F 60%B	
2 R	F 25%B	F 80%B	F 80%B	F 80%B	
3 R	F x 70%B	F 95%B	F 100%B	F 50%B	

* Rings broken, + collapsed, x partially collapsed

Cylinder No.	Ring Groove Carbon Filling and Oil Groove Lacquer					
	Groove Filling, %				Oil Groove Lacquer	
	Fire	No.1	No.2	No.3	Upper	Lower
1 L	10	90	2	0	3.0	3.0
2 L	5	85	5	0	3.0	3.0
3 L	10	95	2	0	3.0	3.0
1 R	15	85	10	0	3.0	3.0
2 R	10	85	5	0	3.0	3.0
3 R	5	60	40	1	3.0	3.0

Cylinder No.	Land Description
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Cylinder No.	Skirt Side	
	Thrust	Anti-Thrust
1 L	5.8 Lt. Scuff and Scratches	5.8 Lt. Scratches
2 L	6.0 Lt. Scuff and Scratches	5.5 Lt. Scuff and Scratches
3 L	6.5 Scuff and Lt. Scratches	6.0 Lt. Scratches
1 R	6.0 Lt. Scratches	6.0 Lt. Scuff and Scratches
2 R	7.0 Plate Melt and Scuff	6.0 Lt. Scratches
3 R	6.0 Scuff and Scratch	5.8 Lt. Scuff and Scratches

RATING DATA SHEET - CONTINUED
CI 5136206-6

C. Other Ratings

Combustion Chambers

<u>Cylinder No.</u>	<u>Description</u>	<u>Cylinder No.</u>	<u>Description</u>
1 L	80% AHC	1 R	30% AHC
2 L	75% AHC	2 R	90% AHC
3 L	80% AHC	3 R	80% AHC

Valve Covers, Oil Pan and Cylinder Head Deck

Covers	Clean
Pan	Clean
Deck	Clean

Remarks

No. 2 R Piston and Liner Removed at 85.5 hours.
A New Set Was Installed, and the Test was Finished.

D. Interim Inspections

Zero Test Hours

Inspection

1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

40 Test Hours

Inspection

1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

60 Test Hours

Inspection

1 L	Fire Ring Black, Scuffed and Glazed Thrust Side of Liner
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

RATING DATA SHEET - CONTINUED
CI 5136206-6

D. Interim Inspections (Cont'd)

80 Test Hours

Inspection

1 L	Fire ring black, lightly burned; Light to medium scuffing of liner thrust side
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

120 Test Hours

Inspection

1 L	Top ring burning, medium glazing to scuffing of liner
2 L	Top land with medium carbon deposits, Light to Medium Lacquer or Glazing of liner
3 L	Normal
1 R	Fire ring face black, lightly burned; Cylinder liner has light to medium glazing
2 R	Normal
3 R	Cylinder liner medium glazing

140 Test Hours

Inspection

1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

160 Test Hours

Inspection

1 L	No change
2 L	No change
3 L	No change
1 R	No change
2 R	No change
3 R	No change

180 Test Hours

Inspection

1 L	No change
2 L	No change
3 L	No change
1 R	No change
2 R	No change
3 R	No change

RATING DATA SHEET - CONTINUED
CI 5136206-6

D. Interim Inspections (Cont'd)

200 Test Hours

Inspection

1 L

No change

2 L

No change

3 L

No change

1 R

No change

2 R

No change

3 R

No change

RATING DATA SHEET
CI 5136206-6
FAILED CYLINDER 2-RIGHT

Test Run at AFLRL
Test Lubricant: AL-7235-1
Test Fuel: CAT 1-H
Test No.: CI 5136206-6
Test Stand: S
Engine No.: 6V53T 5136206
Test Hours: 85.5 for Failed Cylinder
Date Started: 26 June 1979
Date Completed: 30 July 1979

A. Cylinder Liner Ratings

Intake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
2 R	<1%

Scuffing, Glazing and Lacquer*

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>Total</u>	<u>Glazing, %</u>	<u>Lacquer, %</u>
2 R	95	15	55	5	95

* Ring Travel Area.

B. Piston Ratings

Ring Sticking and Condition

<u>Cylinder No.</u>	<u>Fire</u>	<u>Ring</u> <u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
2 R	30% C.S., 30%B P, X, 55%	F 100%B	F 100%B	F 100%B

X = Partially collapsed
CS = Cold Stuck
F = Free
B = Burned

RATING DATA SHEET - CONTINUED
 CI 5136206-6
 FAILED CYLINDER 2-RIGHT

B. Piston Ratings (Cont'd)

<u>Cylinder No.</u>	<u>Ring Groove Carbon Filling and Oil Groove Lacquer</u>					<u>Oil Groove Lacquer</u>	
	<u>Fire</u>	<u>Groove Filling, %</u>				<u>Upper</u>	<u>Lower</u>
		<u>No.1</u>	<u>No.2</u>	<u>No.3</u>			
2 R	5%	90%	2%	<1%		3.0	3.0

<u>Cylinder No.</u>	<u>Land Description</u>
2 R	Start of Plate Melt on fourth land - Rest Normal

<u>Cylinder No.</u>	<u>Skirt</u>	
	<u>Thrust</u>	<u>Side</u> <u>Anti-Thrust</u>
2 R	100% Scuff and Burn	5.5 Light Scratches

RING STICKING

Test No. CI-6

Engine Model 6V53T Serial No. 5136206 Date 8-1-79

Fuel 1-H CAT Lubricant AL-7235-8531-L Observer E Lyons

Piston Number

Ring No.	1L	2L	3L	1R	2R	3R
1	5% P	F	F	F	F	F
2	F	F	F	F	F	F
3	F	F	F	F	F	F
4	F	F	F	F	F	F

Indicate by letter -- Free or Sluggish, or by number and letter -- percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

RING STICKING

Test No. CI-6(85.5 Hours, Failed Cylinder No. 2-Right)

Engine Model 6V53T Serial No. 5136206 Date 8-1-79

Fuel 1-H CAT Lubricant AL-7235-L Observer E. Lyons

Piston Number

Ring No.	1L	2L	3L	1R	2R	3R
1	/	/	/	/	30% C.S. 30% P PARTIALLY COLLAPSED	
2	/	/	/	/	/	/
3	/	/	/	/	/	/
4	/	/	/	/	/	/

Indicate by letter - Free or Sluggish, or by number and letter - percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

PISTON GROOVE INSIDE DIAMETER-% RING SUPPORTING CARBON

Test No. CI-6

Engine Model 6V53T Date 8-1-79

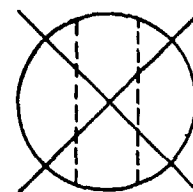
Serial No. 5136206

Fuel 1-H CAT Observer E. Lyons

Lubricant AL-7235-8531-L

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	0	10	90	0	5	0
	2	75	5	100	70	5	10
	3	0	40	10	5	100	10
	4	0	0	0	0	5	0

1 Thrust Side



4 Front

2 Rear

3 Anti-Thrust Side

PISTON GROOVE INSIDE DIAMETER-% RING SUPPORTING CARBON

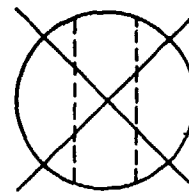
Test No. CI-6 (85.5 Hours, Failed Cylinder No. 2-Right)

Engine Model 6V53T Serial No. 5136206 Date 8-1-79

Fuel 1-H CAT Lubricant AL-7235-8531-L Observer E. Lyons

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1					0	
	2					0	
	3					0	
	4					0	
2	1					95	
	2					10	
	3					100	
	4					95	

1 Thrust Side



4 Front

2 Rear

3 Anti-Thrust Side

VALVE DEPOSITS

Test No. CI-6

Engine Model 6V53T Serial No. 5136206 Date 8-1-79

Fuel 1-H CAT Lubricant AL-7235-8531-L Observer E. Lyons

Cylinder Number													
		1L			2L			3L			1R		
		CARB	LACQ		CARB	LACQ		CARB	LACQ		CARB	LACQ	
Head*	INT												
	EXH	100	AHC										
Face	INT	1/4 AHC			100	-		9 LACQUER					
	EXH												
Tulipt	INT	100	AHC			100	-	9 LACQUER					
	EXH												
Stem	INT	NUMBER	9 LACQUER					CLEAN					
	EXH												

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S, (Page 5).

Lacquer: Pages 4, 36 and 37.

EXHAUST VALVE SURFACE CONDITIONS

Test No. CI-6

Engine Model 6V53T













Serial No. 5136206

Date 8-1-79

Fuel 1-H CAT

Lubricant AL-7235-8531-L

Observer E. Lyons

	1L	2L	3L	1R	2R	3R
Freeness in Guide	F			(All Free)		
Head	N			(All Normal)		
Face	N			(All Normal)		
Seat	N			(All Normal)		
Stem	N			(All Normal)		
Tip	N			(All Normal)		

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

TAPPETS, CAMS, AND ROCKER ARMS

Test No. CI-6

Engine Model 6V53T Serial No. 5136206 Date 8-1-79
 Fuel 1-H CAT Lubricant AL - 7235-8531-L Observer E. Lyons

		Cylinder Number					
		1L	2L	3L	1R	2R	3R
Tappet Deposit	INT						
	EXH						
	INJ						
Tappet Surface Condition	INT						
	EXH						
Cam Lobes							
Rocker Arms	Tip	INT					
		EXH					
	Bushing	INT					
		EXH					
	Shaft	INT					
		EXH					

Lacquer: Pages 4, 36 and 37 of Manual.
 See Pages 1, 2, 16 through 23, and 54 through 65.

SURFACE CONDITION

Test No. CI-6

Engine Model 6V53T Serial No. 5136206 Date 8-1-79
 Fuel 1-H CAT Lubricant AL-7235-8531-L Observer E. Lyons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing	Scratched Babbitt Removed	Same	Same	Scratched	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX
	N	N	N	N	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX
Rod-Bearing	*LIGHT	SCRATCHES					
-Journal	N	N	N	N	N	N	
	N	N	N	N	N	N	
Piston Pin							
Bushing	ALL BUSHINGS ROD BUSHINGS	IN PISTONS	WORN AT TOP				

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

*No. 1-Left has a deep scratch on to half.

SURFACE CONDITION

Test No. CI-6 (85.5 Hours, Failed Cylinder No. 2-Right)

Engine Model 6V53T

Serial No. 5136206

Date 8-1-79

Fuel 1-H CAT

Lubricant AL-7235-L

Observer E. Lyons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing							
Rod-Bearing							
Piston Pin	R2 WORN AND SCUFFED ON BEARING SURFACE						
Bushing	WORN HEAVY ON TOP						

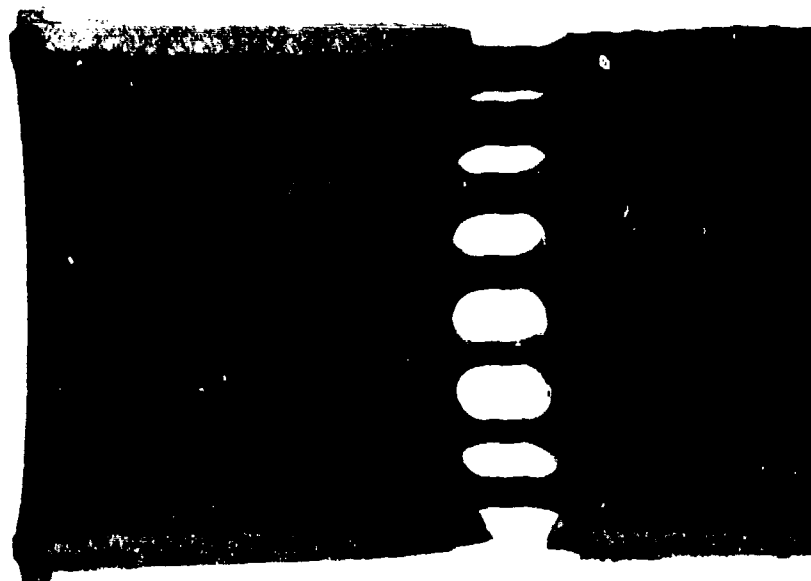
Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



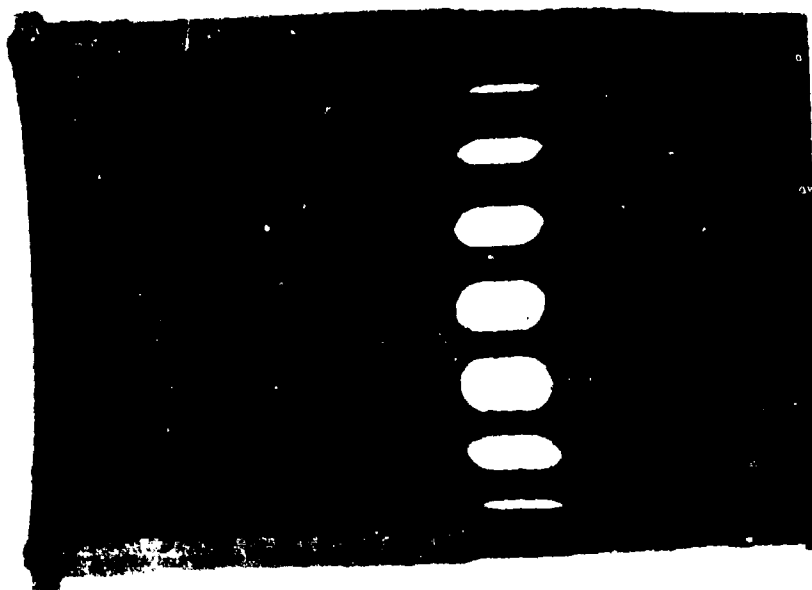
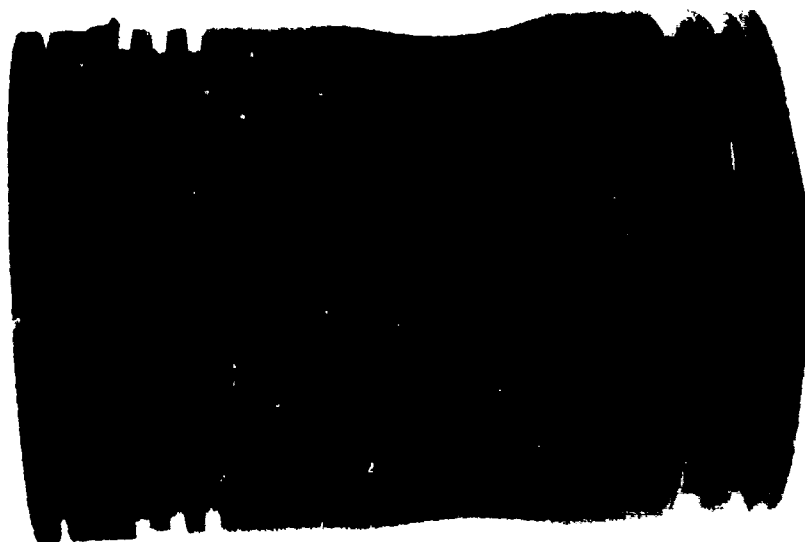
1-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



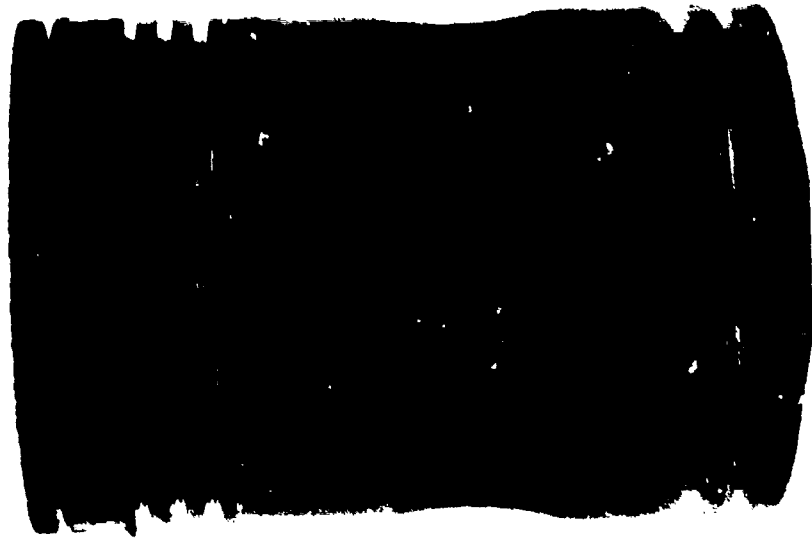
1-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

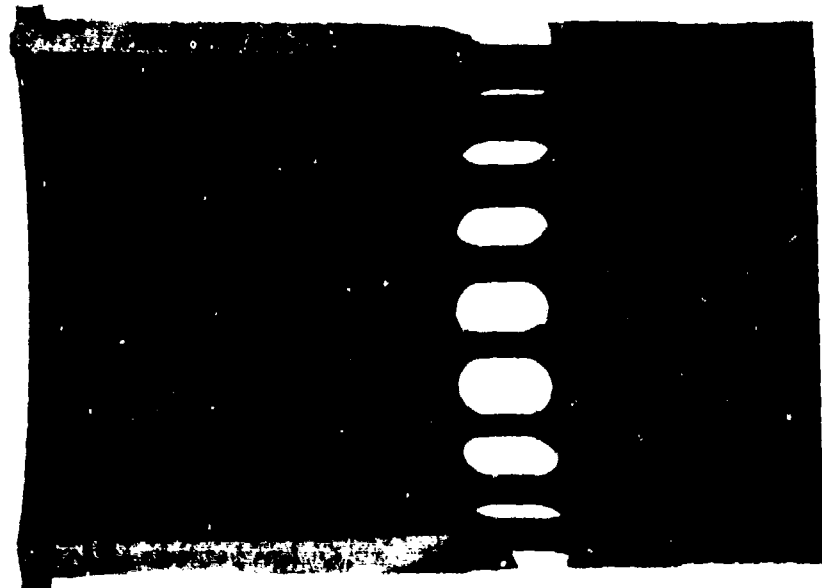
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



2-RIGHT THRUST

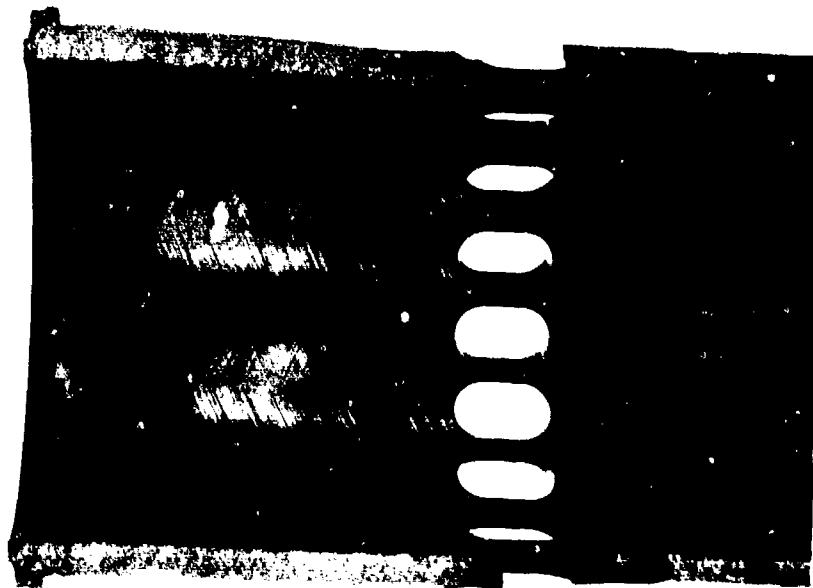


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



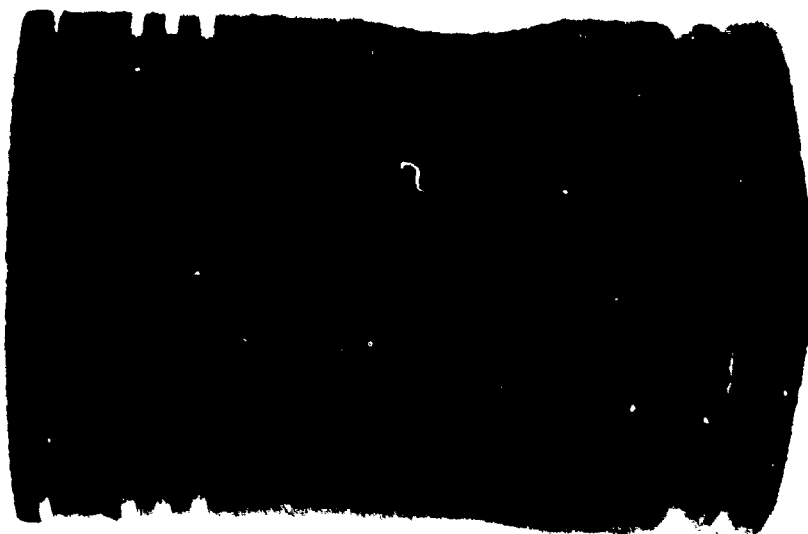
2-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

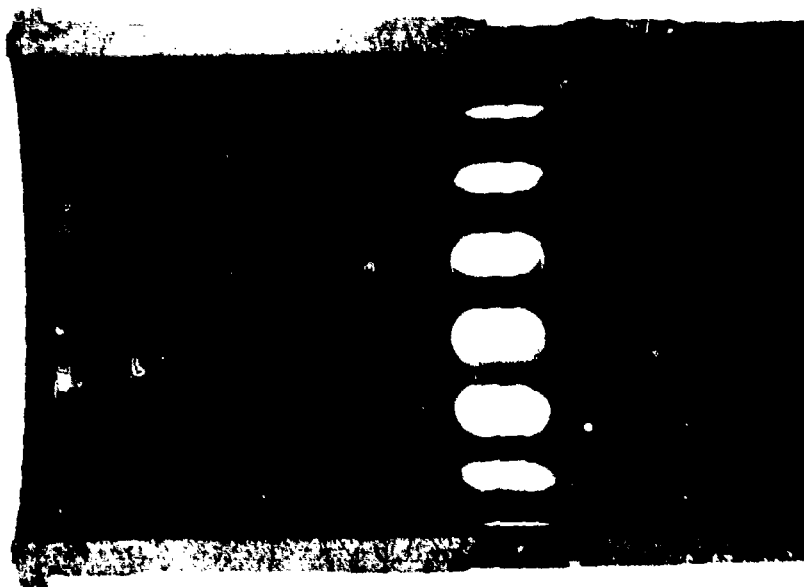
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



3-RIGHT THRUST

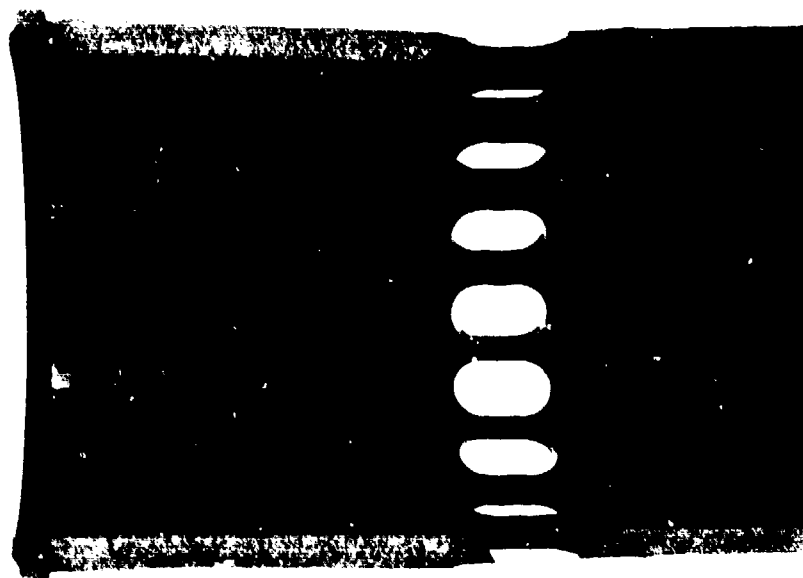
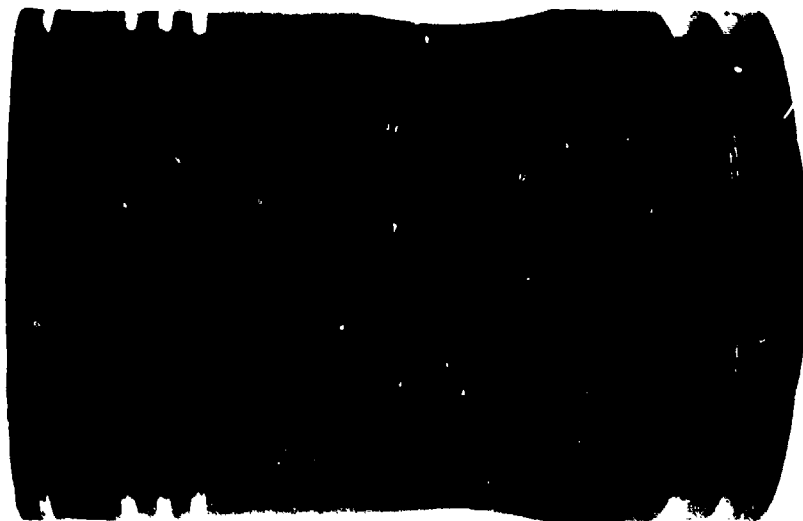


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



3-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



1-LEFT THRUST

1 - LT

CYLINDER

PHOTO

MISSING

OR

NOT

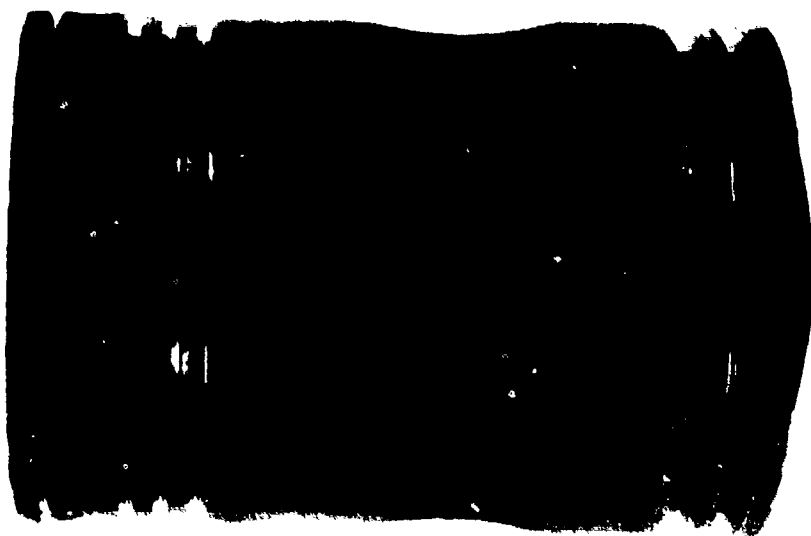
TAKEN

CONDITION OF PISTON AND CYLINDER LINER

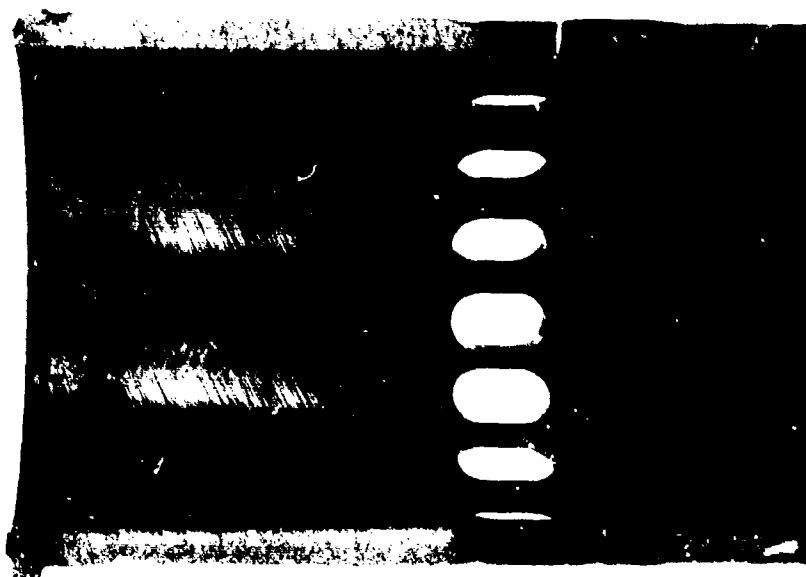
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



1-LEFT ANTI-THRUST



CONDITION OF PISTON AND CYLINDER LINER

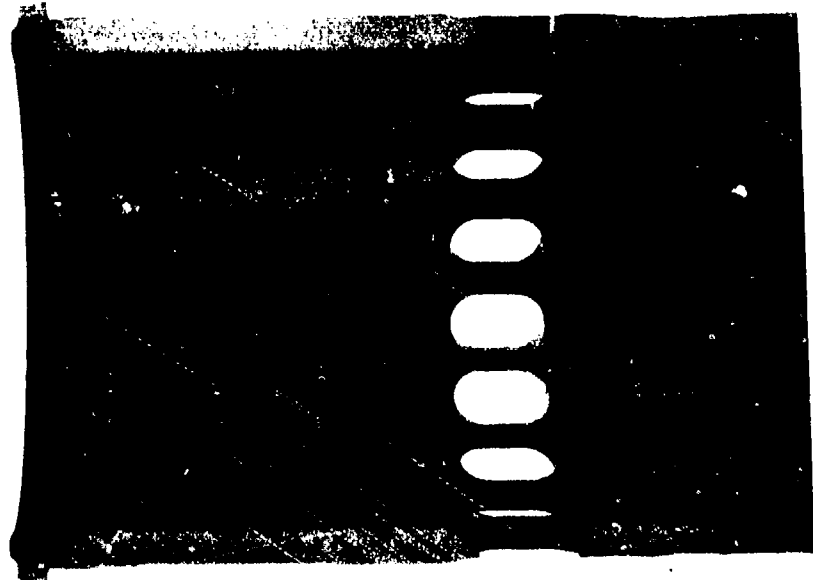
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



2-LEFT THRUST

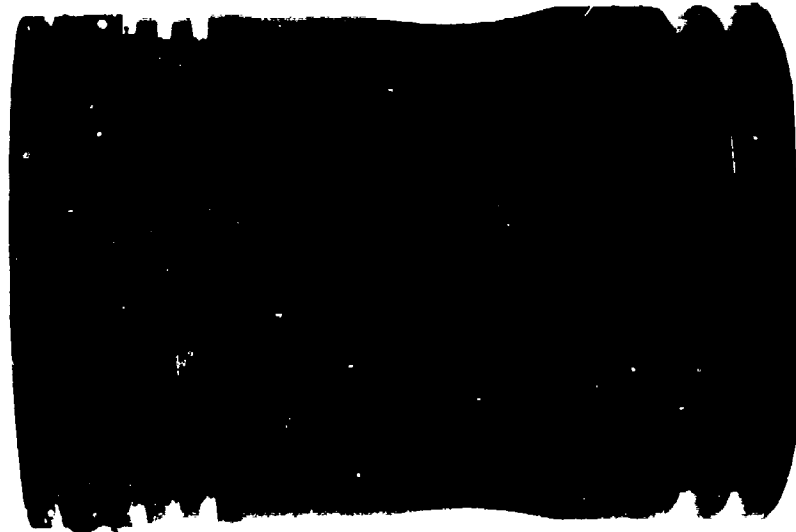


CONDITION OF PISTON AND CYLINDER LINER

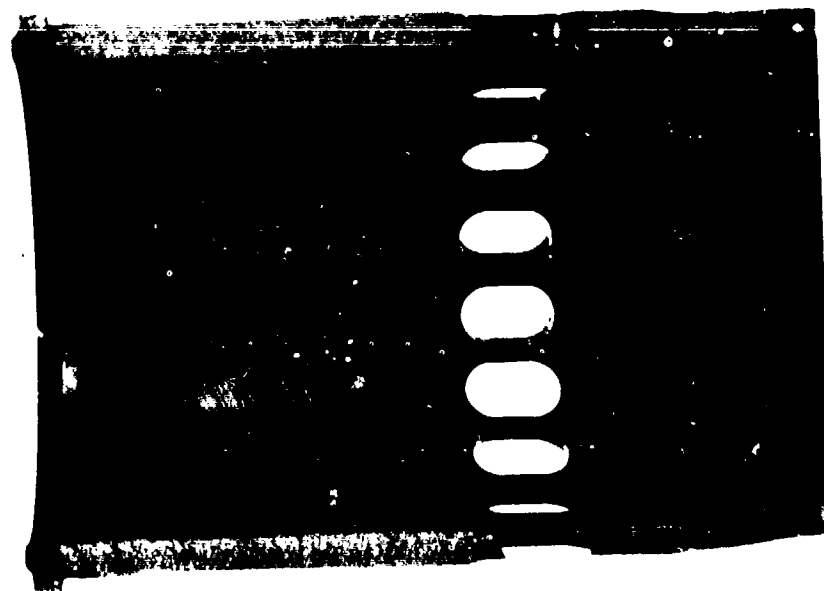
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



2-LEFT ANT:1-THRUST

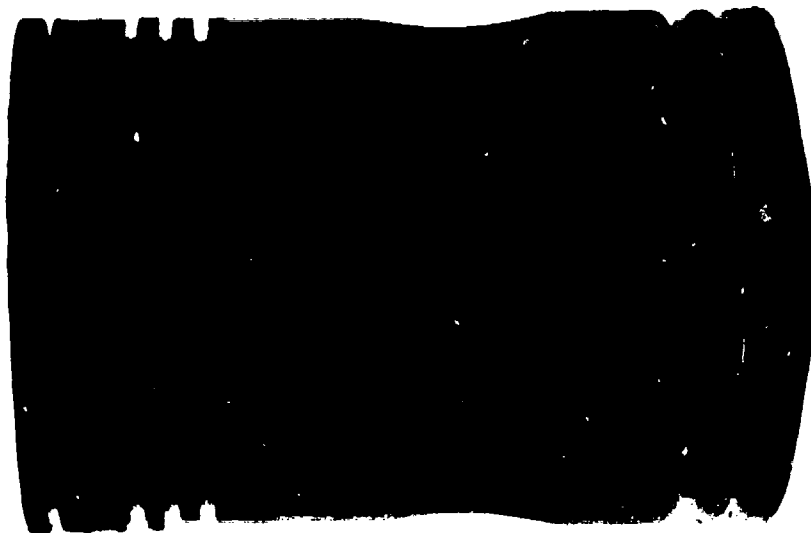


CONDITION OF PISTON AND CYLINDER LINER

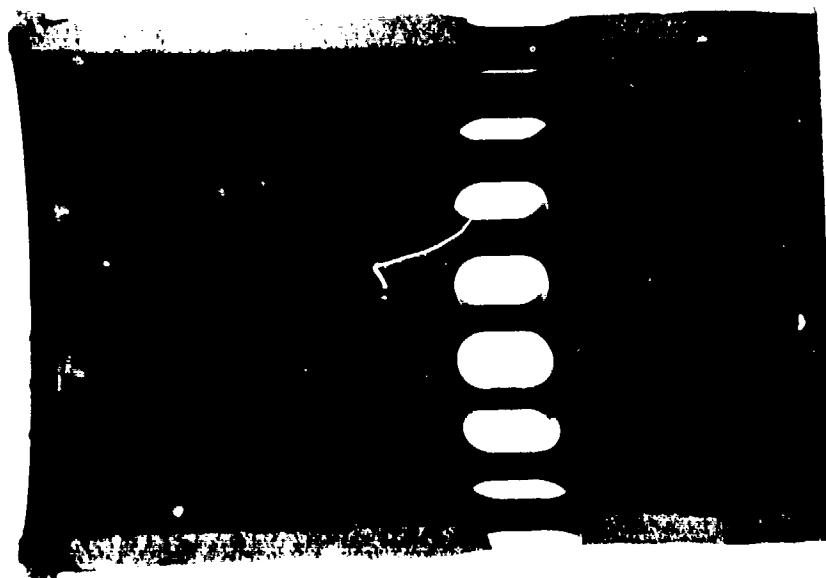
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



3-LEFT THRUST

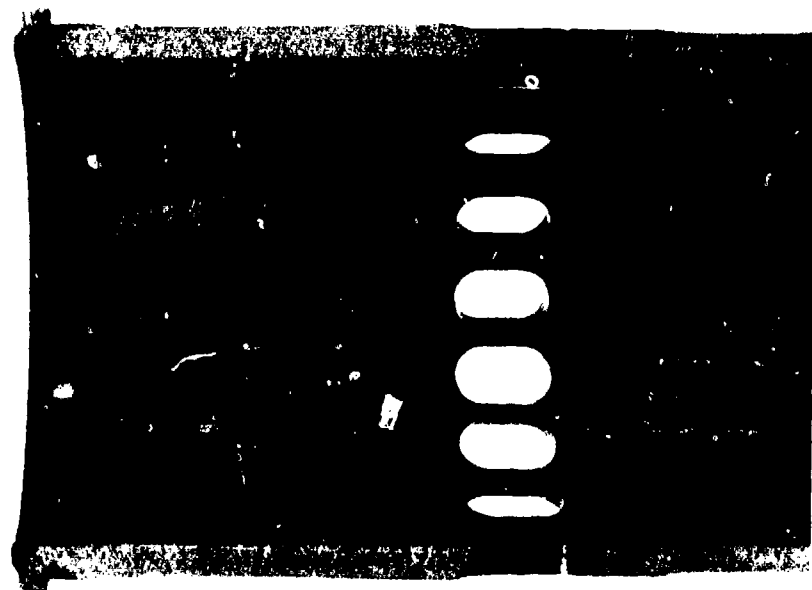


CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



3-LEFT ANTI-THRUST

CONDITION OF FAILED PISTON AND CYLINDER

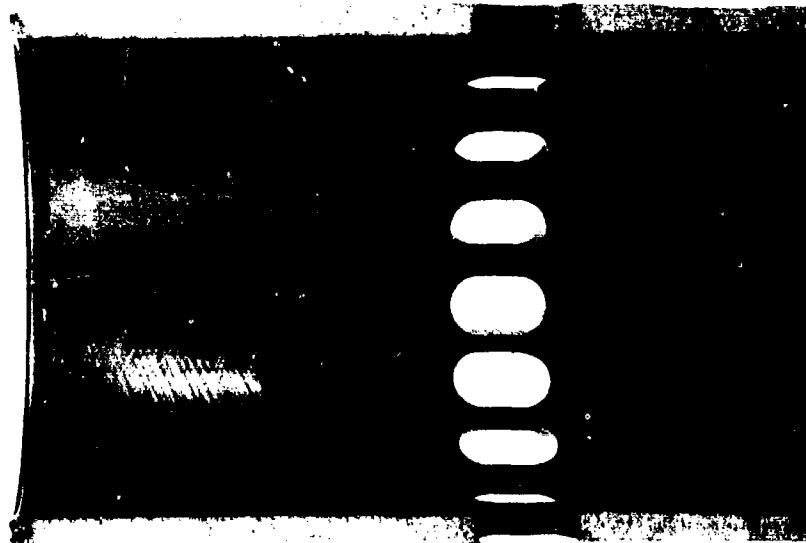
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-L



2-RIGHT THRI 'ST

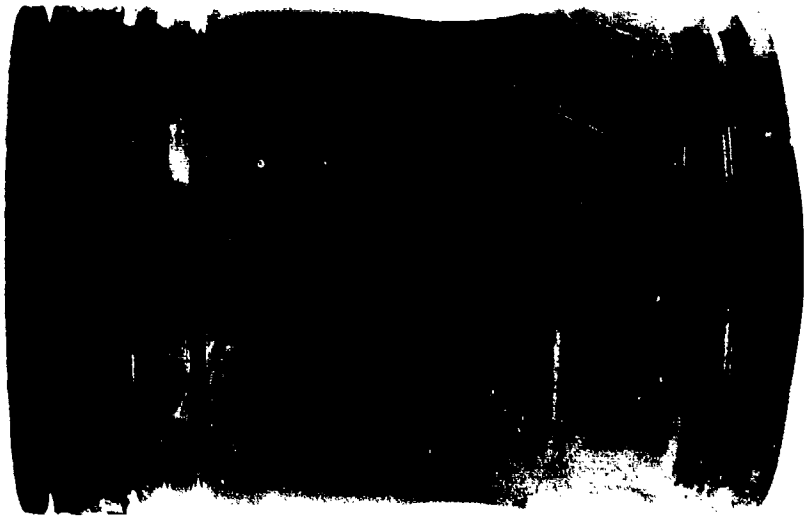


CONDITION OF FAILED PISTON AND CYLINDER

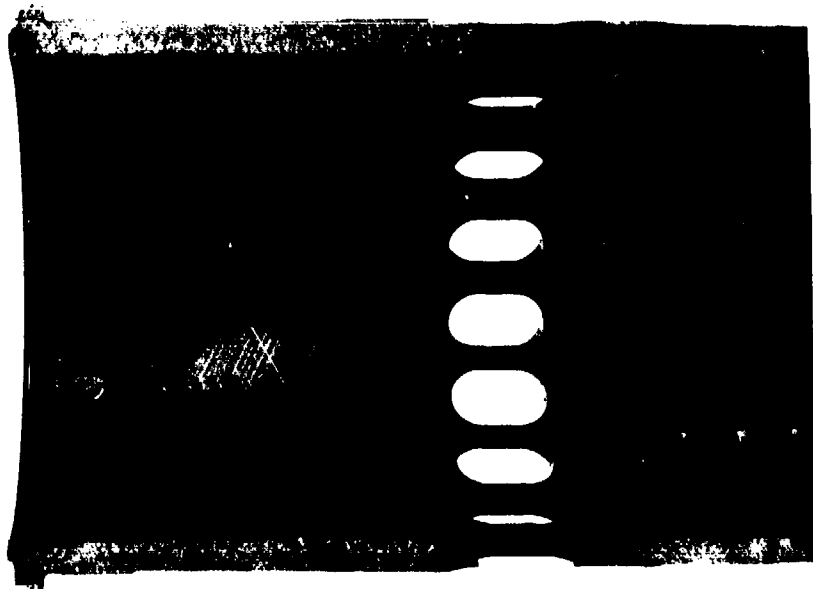
TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-L



2-RIGHT ANTI-THRUST



CONDITION OF RING FACES

TEST TIME: 240 HOURS

TEST NO.: CI5136206-6

LUBRICANT: AL-7235-8531-L



1-RIGHT



2-RIGHT



3-RIGHT

CONDITION OF RING FACES

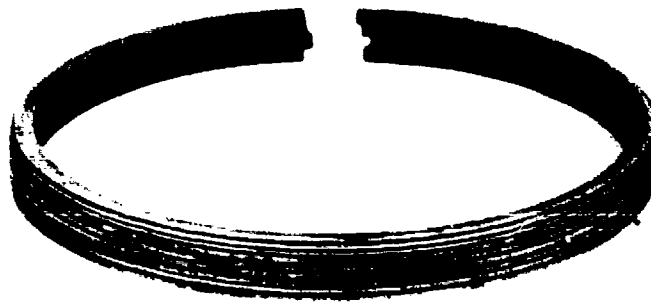
TEST TIME: 240 HOURS

TEST NO.: CI5136206-6

LUBRICANT: AL-7235-8531-1



1-LEFT



2-LEFT



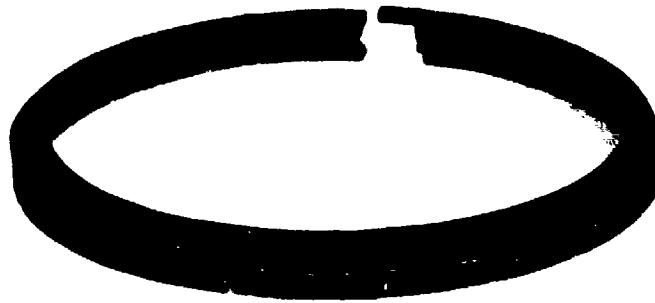
3-LEFT

CONDITION OF FAILED RING FACES

TEST TIME: 120 HOURS

TEST NO.. CI 5136206-6

LUBRICANT: AL-7235-L



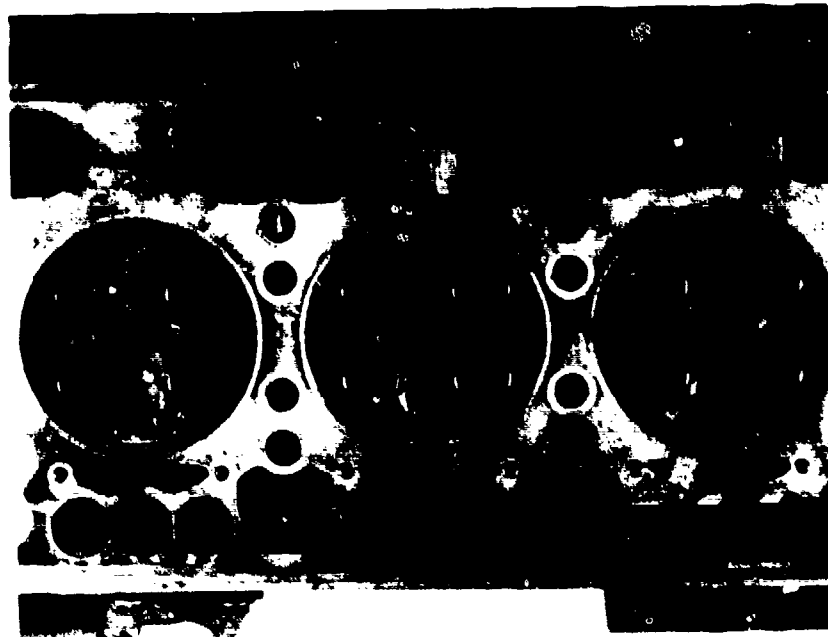
2-RIGHT

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

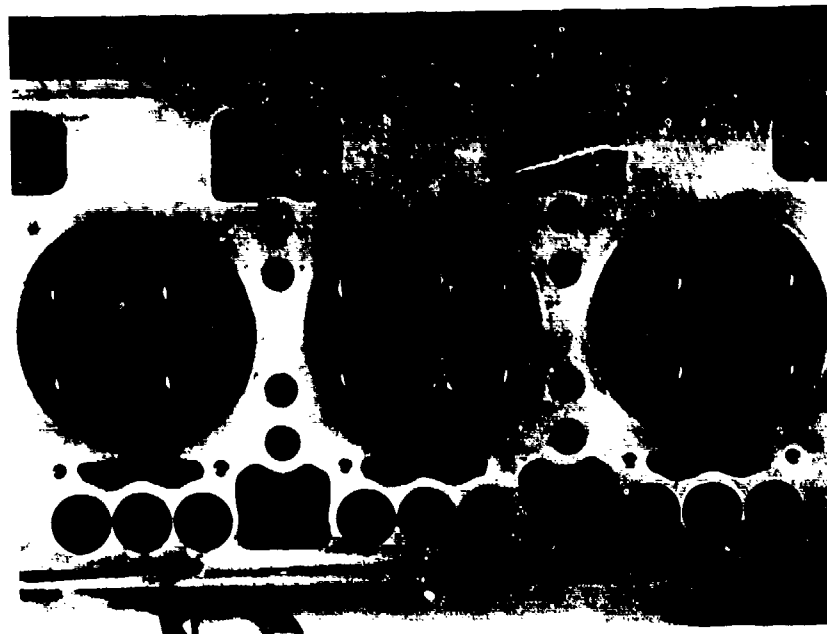
LUBRICANT: AL-7235-8531-L



1L

2L

3L



3R

2R

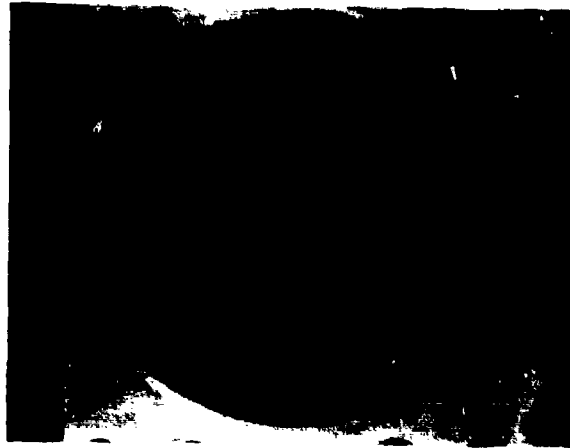
1R

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



1-RIGHT



2-RIGHT



3-RIGHT

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



1-LEFT



2-LEFT



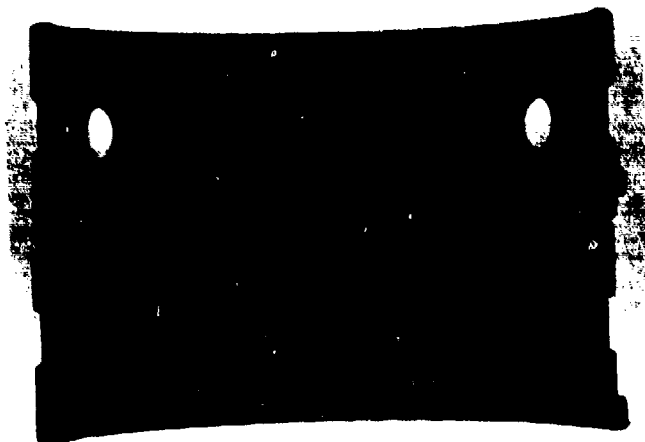
3-LEFT

CONDITION OF ROD BEARINGS

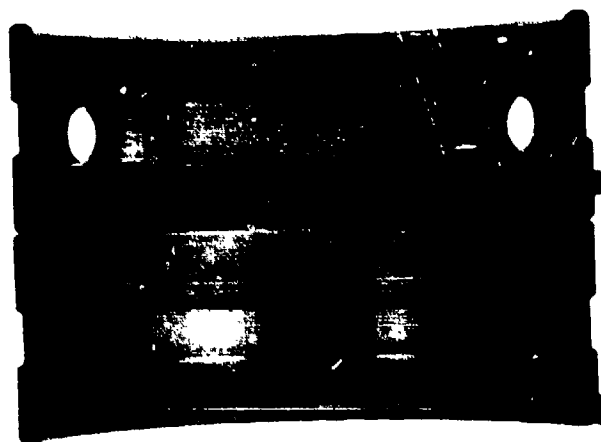
TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

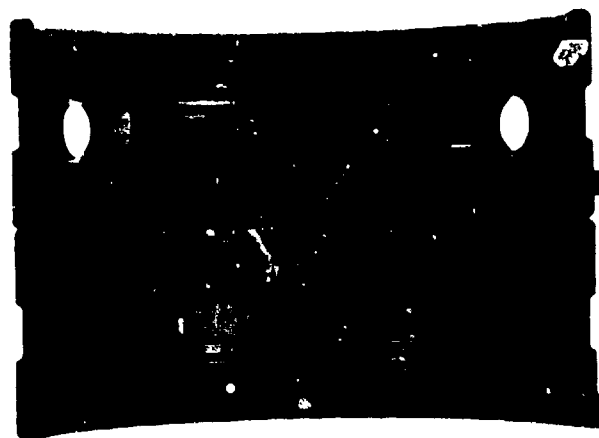
LUBRICANT: AL-7235-8531-L



1-RIGHT



2-RIGHT



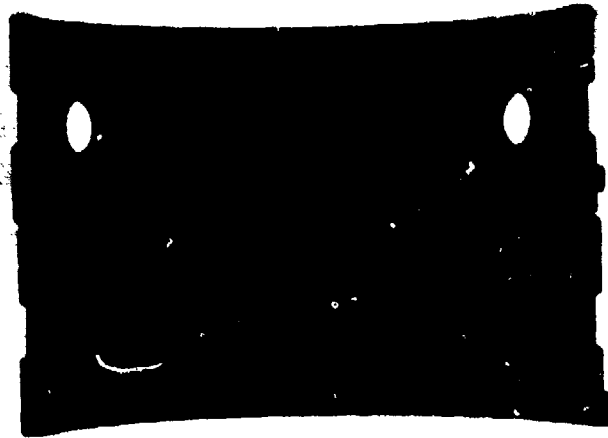
3-RIGHT

CONDITION OF ROD BEARINGS

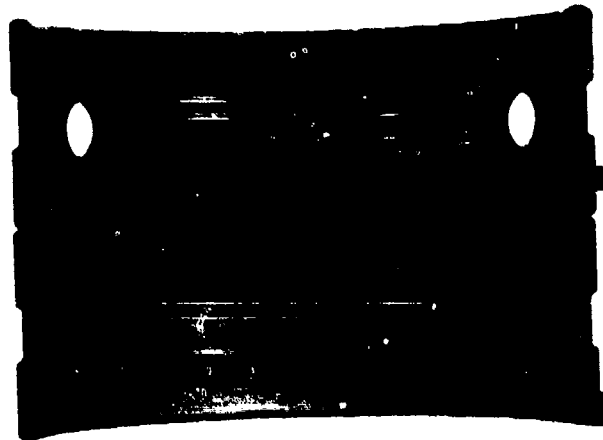
TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

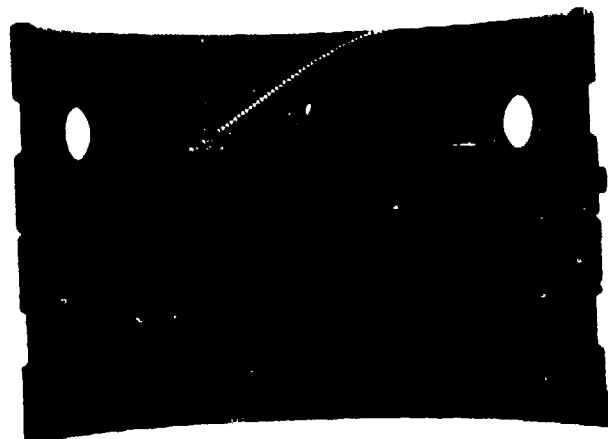
LUBRICANT: AL-7235-8531-L



1-LEFT



2-LEFT



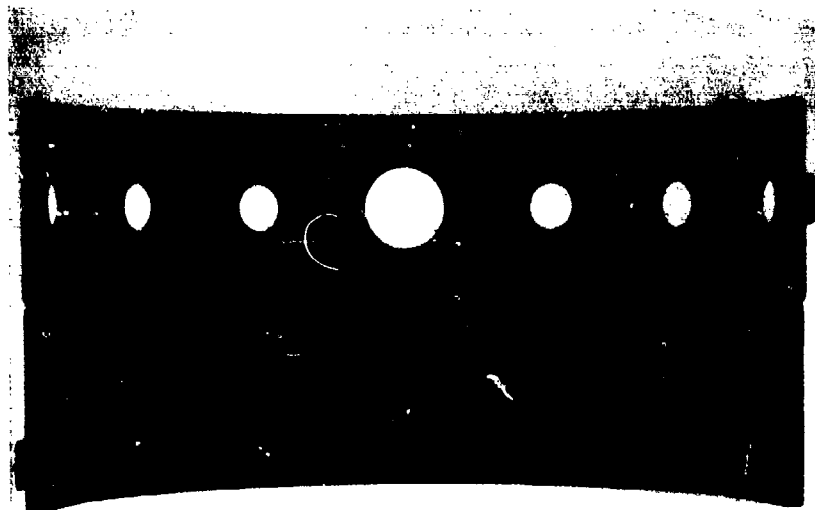
3-LEFT

CONDITION OF MAIN BEARINGS

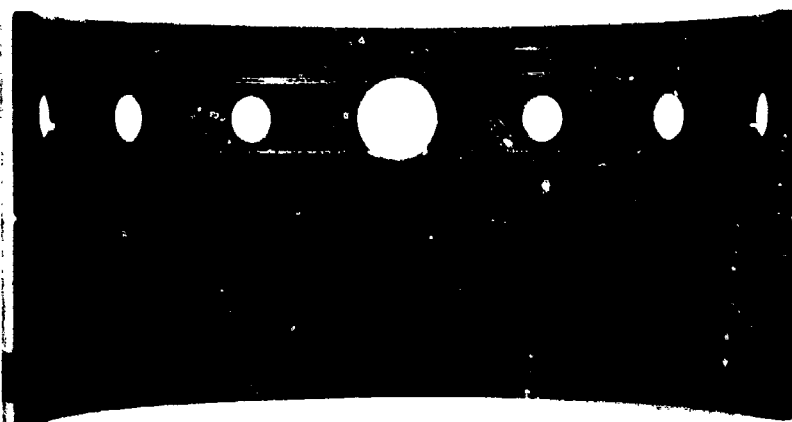
TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



NO. 1



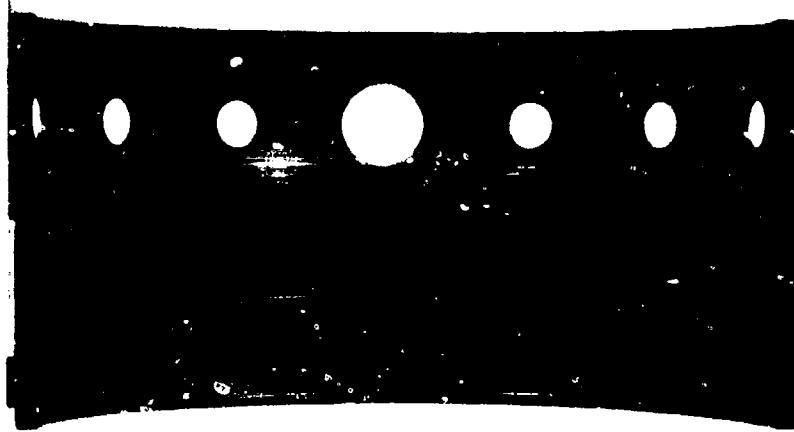
NO. 2

CONDITION OF MAIN BEARINGS

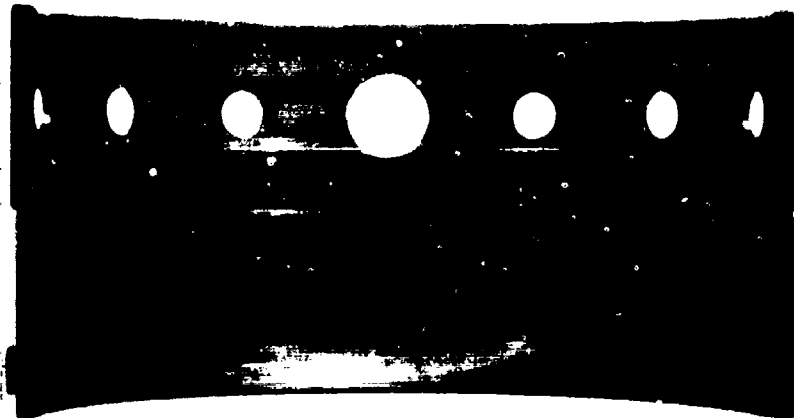
TEST TIME: 240 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-8531-L



NO. 3



NO. 4

D-64

CONDITION OF FAILED PISTON PIN BUSHING

TEST TIME: 120 HOURS

TEST NO.: CI 5136206-6

LUBRICANT: AL-7235-L



← UPPER
HALF

← LOWER
HALF

2-RIGHT

APPENDIX E

ENGINE-LUBRICANT COMPATIBILITY TEST #7

240-HOUR TRACKED-VEHICLE CYCLE

USING 6V-53T DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V53T DIESEL ENGINE

Test Lubricant: AL-8406-L
Engine Test Number: CI5136206-7
Date Completed: 31 August 1979

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Ft. Belvoir, Virginia

by

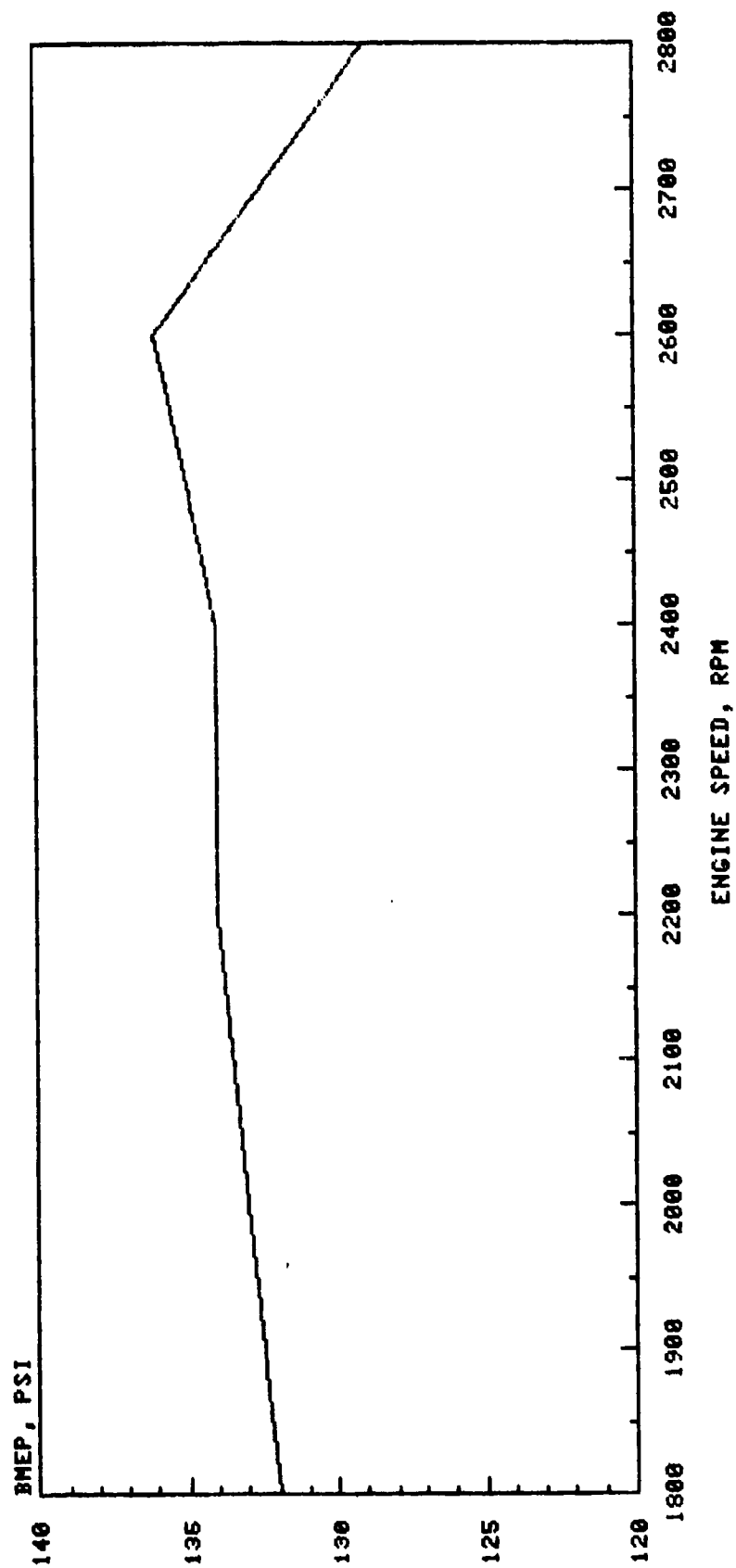
U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V53T
BUILD-UP ENGINE MEASUREMENTS
CI5136206-7

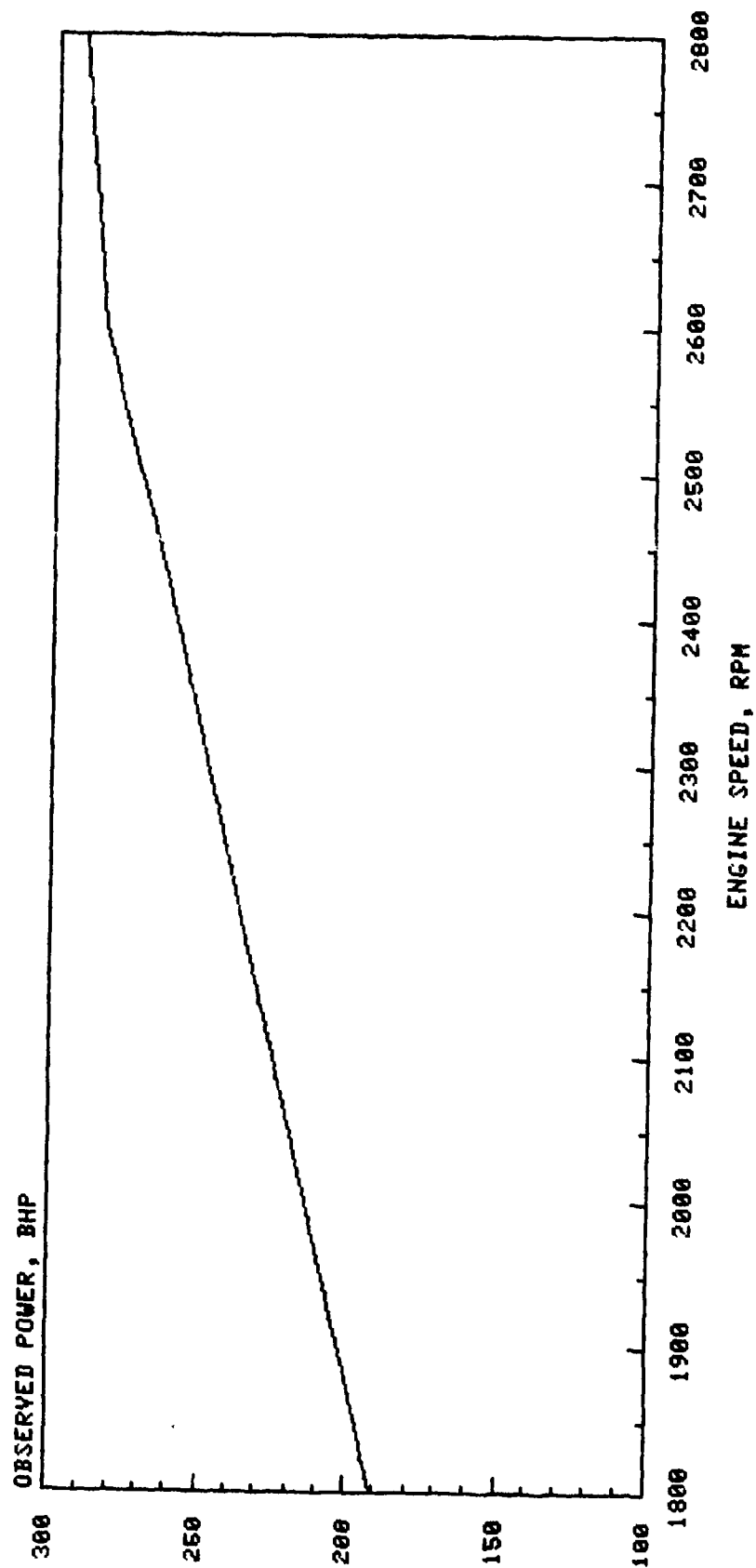
Measurements	Inches			
	Min	Max	Avg	Spec. Limits (1)
Connecting rod bearing clearance	0.0026	0.0034	0.0030	0.0016-0.0046
Cylinder Liner block bore				
Taper	0.0001	0.0005	0.0002	0.0015 max
Out-of-round	0.0000	0.0006	0.0003	0.0015 max
Inside diameter	4.3571	4.3578	4.3575	4.3595 max
Cylinder Liners (installed)				
Taper	0.0002	0.0008	0.0004	0.0020 max (2)
Out-of-round	0.0000	0.0007	0.0002	0.0030 max (2)
Inside diameter	3.8753	3.8764	3.8759	3.8752-3.8767
Piston to liner fit	0.0073	0.0084	0.0077	0.0060-0.0095
Piston Diameter	3.8664	3.8685	3.8675	3.8669-3.8691
Fire Ring				
End gap	0.026	0.034	0.031	0.020-0.046
Side clearance	0.003	0.004	0.003	0.003-0.006
No. 1 Compression Ring				
End gap	0.030	0.040	0.033	0.020-0.046
Side clearance	0.008	0.009	0.009	0.007-0.010
No. 2 & No. 3 Compression Ring				
End gap	0.029	0.037	0.031	0.020-0.046
Side clearance	0.006	0.007	0.006	0.005-0.010
Oil rings				
End gap	0.017	0.023	0.019	0.010-0.025
Side clearance	0.003	0.003	0.003	0.0015-0.0055

- (1) Limits on new parts unless maximum wear limit specified.
(2) Wear limits with new liners in a used block.

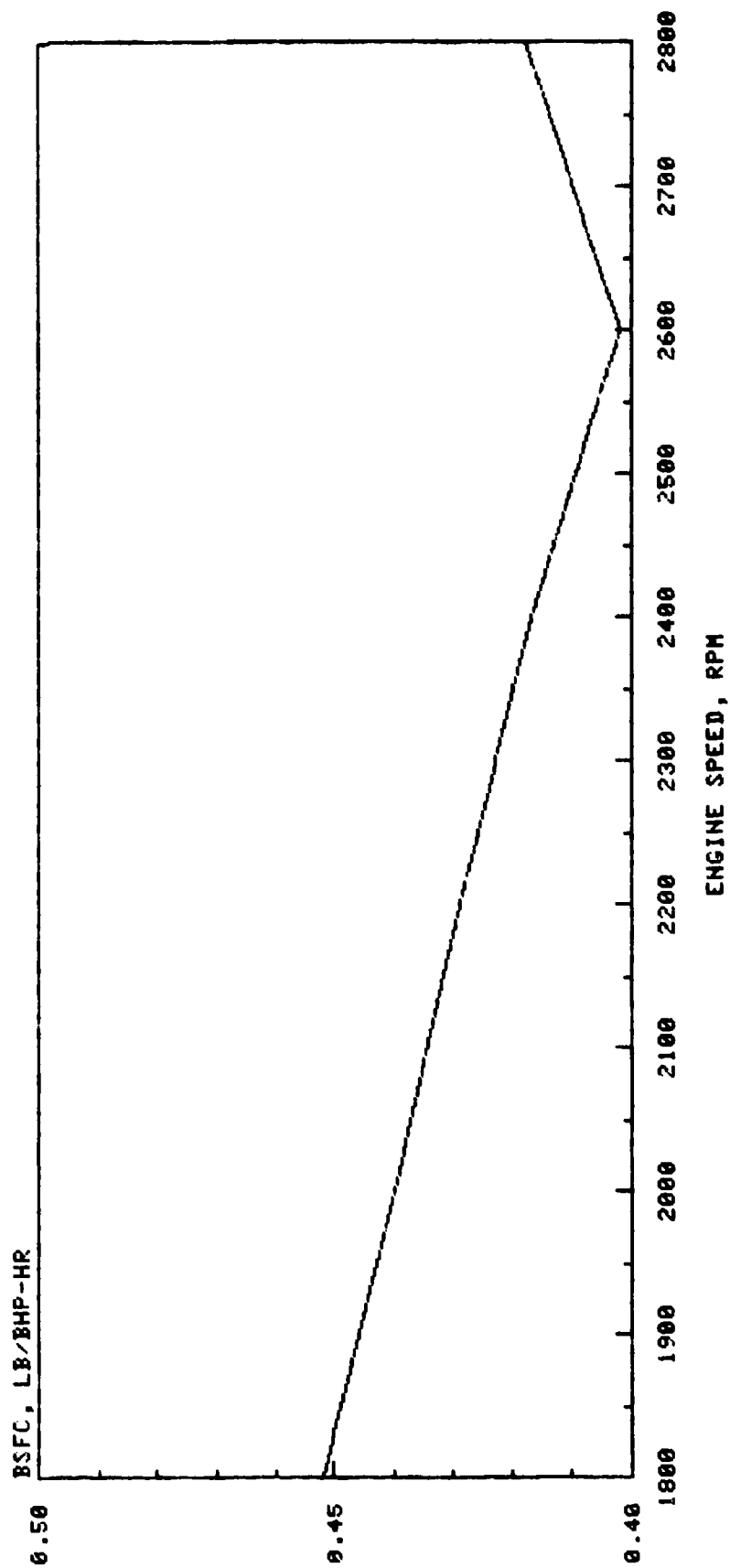
6V53T ENDURANCE TEST-240 HR TRACKED
Test No. C15136206-7 Lubricant: AL-8406-L



6V53T ENDURANCE TEST-240 HR TRACKED
Test No. C15136206-7 Lubricant: AL-8406-L



6V53T ENDURANCE TEST-240 HR TRACKED
Test No. CIS136206-7 Lubricant: AL-8406-7



6V53T ENDURANCE TEST
SUMMARY OF OPERATING DATA

Test No.: CI5136206-7

Lubricant: AL-8406-L

	2200 RPM			2800 RPM		
	<u>Avg</u>	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Engine Speed, rpm	2204	1997	2201	2803	2793	2813
Load, lb	450	424	476	433	416	450
Obs. Power, bhp	242	207	256	296	283	309
Fuel Rate, lb/hr	99.0	93.8	104.2	121.9	118.8	125.0
BSFC, lb/bhp-hr	.409	.407	.453	.412	0.405	0.420

Temperatures, °F

Jacket In	151	145	157	141	137	145
Jacket Out	165	159	171	155	152	158
Oil Sump	247	242	252	247	242	252
Inlet Air (Compressor)	97	88	106	99	90	108
Airbox	235	222	248	277	251	303
Exhaust before Turbo	1128	1022	1234	1127	1011	1243
Exhaust after Turbo	953	886	1020	950	877	1023
Fuel at filter	90	86	94	92	89	95

Pressures, psi

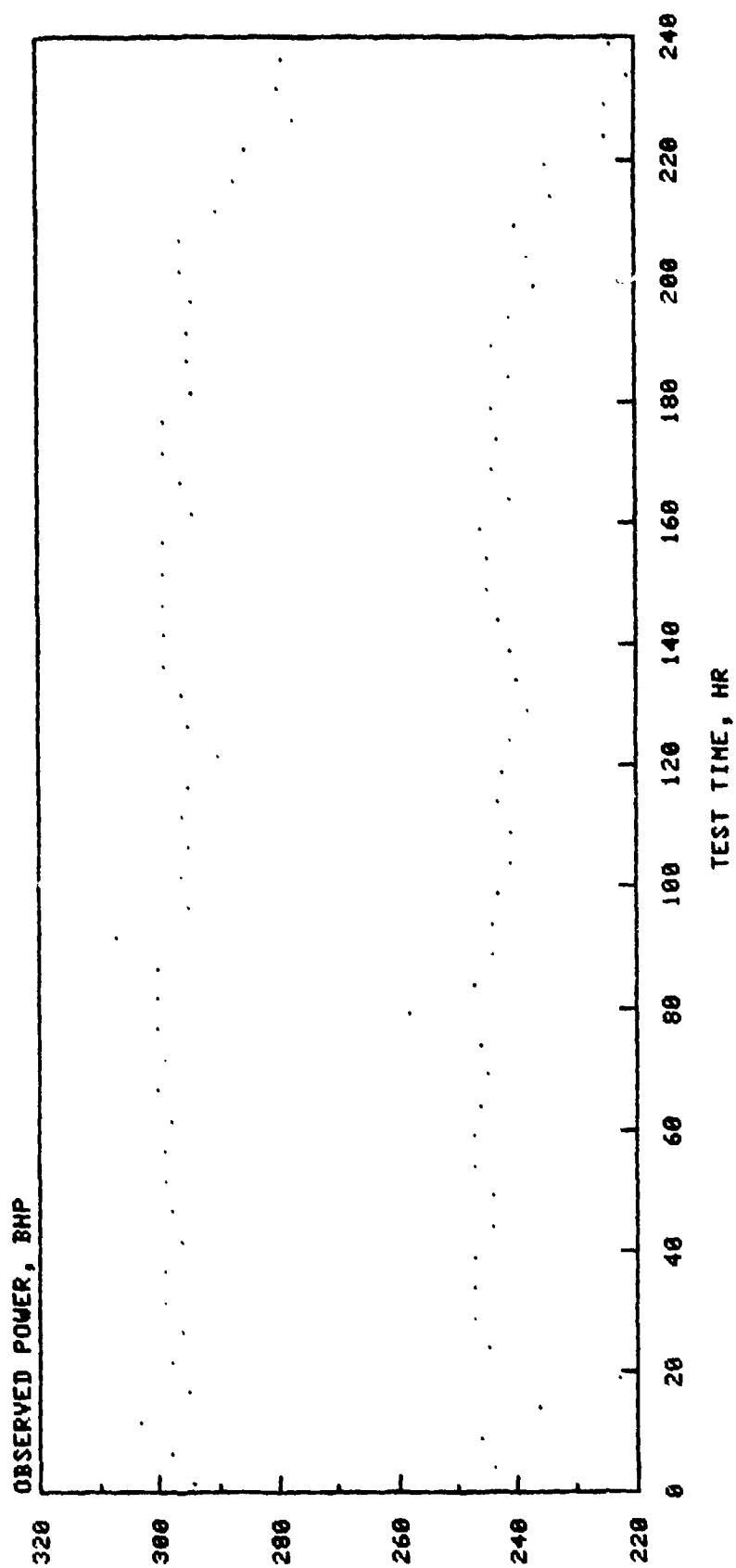
Compressor Discharge	8.2	7.5	8.9	11.3	10.3	12.3
Blower Discharge	10.1	9.3	10.9	16.9	16.1	17.6
Exhaust Before Turbo	8.7	8.0	9.4	12.8	12.1	13.5

Oil Consumption (lb/hr
avg for 240 hr) 0.455

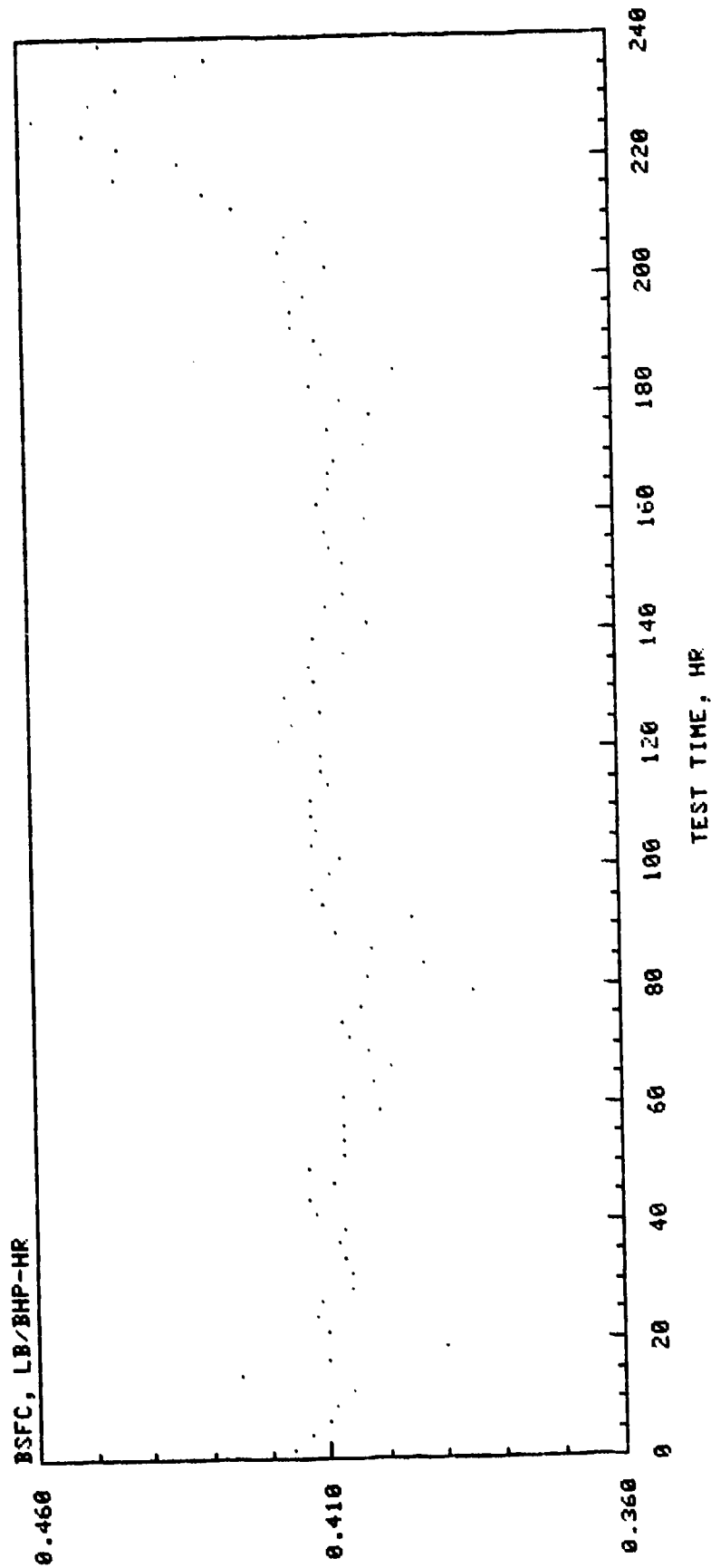
Unscheduled Shutdowns

1. At 0.5 hours-stopped engine to replace broken oil line; added 20.64 lb oil
2. At 2.5 hours-stopped engine to replace other broken line; added 13.48 lb oil.

6V55T ENDURANCE TEST-240 HR TRACKED
Test No. C15136206-7 Lubricant: AL-8406-L



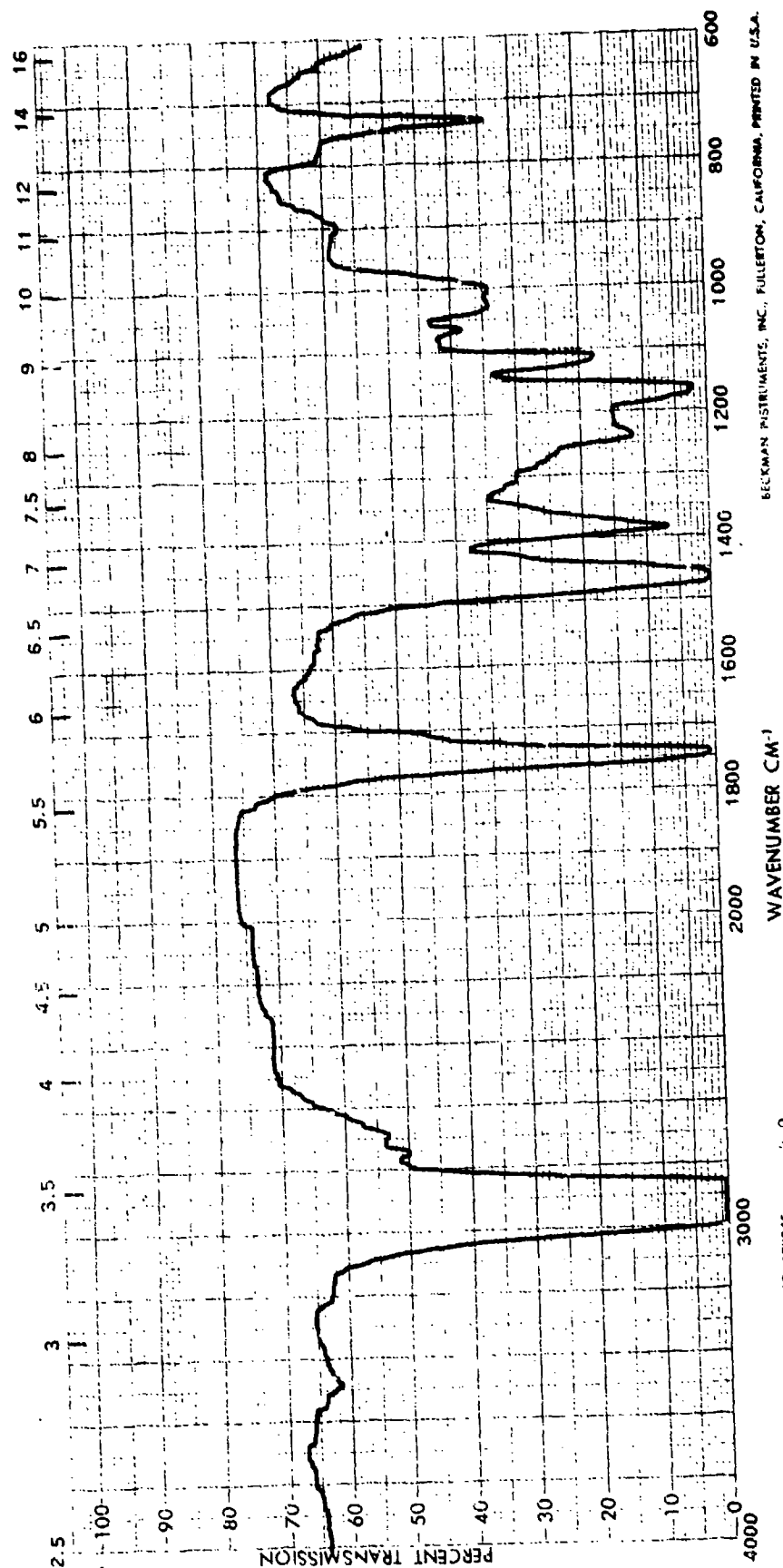
6V53T ENDURANCE TEST-240 HR TRACKED
Test No. CI5136206-7 Lubricant: AL-8406-L



LUBRICANT ANALYSIS
6V53T - CI5136206-7
LUBRICANT: AL-8406-L
FUEL: I-H CAT

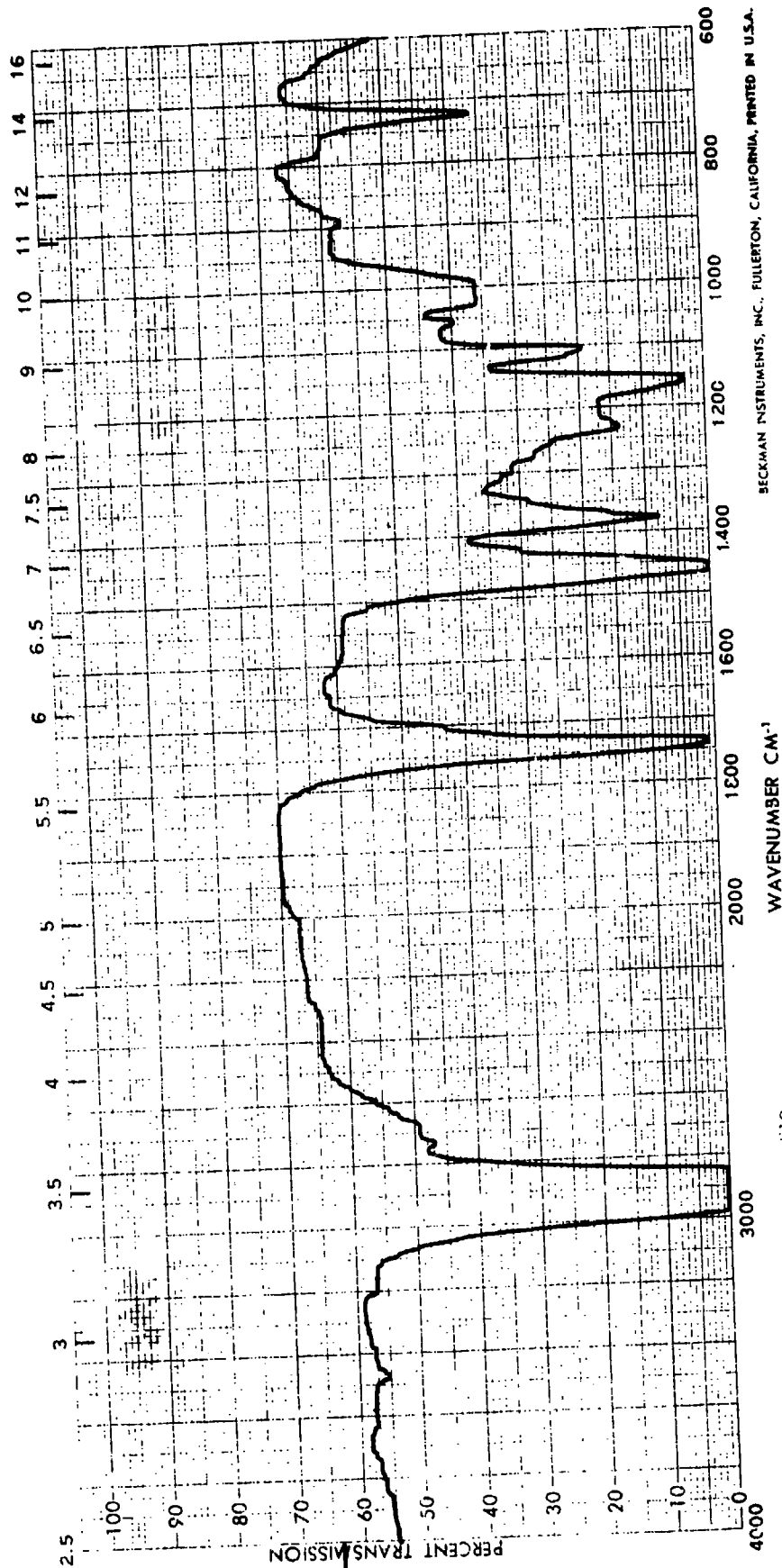
Property	ASTM Test Method	New	TEST HOUR												
			20	40	60	80	100	120	140	160	180	200	220	240	
Cold Cranking Simulator @ -29°C, cP	D 2602	-													4000
Cold Cranking Simulator @ -18°C, cP	D 2602	1600													1400
K. Vis. @40°C, cSt	D 445	56.0	54.1			54.7		57.4		53.9		54.5		57.0	
K. Vis. @100°C, cSt	D 445	10.0	9.53			9.57		9.72		9.51		9.53		9.53	
TAN	D 664	3.0	2.65			2.63		2.56		2.61		2.56		2.50	
TBN	D 664	6.3	2.17			2.16		2.11		2.13		2.10		2.15	
TBN	D 2896	7.1													
Insolubles, %															
Pentane B	D 893	0.04	0.02			0.04		0.03		0.03		0.03		0.06	
Toluene B	D 893	0.02	0.02			0.03		0.03		0.02		0.02		0.06	
Flash Point, °C	D 92	224						218						216	
Pour Point, °C	D 97	-45						-42						-45	
Gravity, °API @60°F	D 287	31.2						30.6						29.4	
Carbon Residue, wt %	D 524	1.07						1.53						2.71	
Sulfated Ash, wt %	D 874	1.05						1.27						1.24	
Millipore Insolubles, wt %		-	0.07			0.08		0.04		0.03		0.06		0.10	
Wear Metals by XRF															
Iron, ppm		-	51	85	93	93	87	107	44	56	64	85	164	202	

- = Not determined.

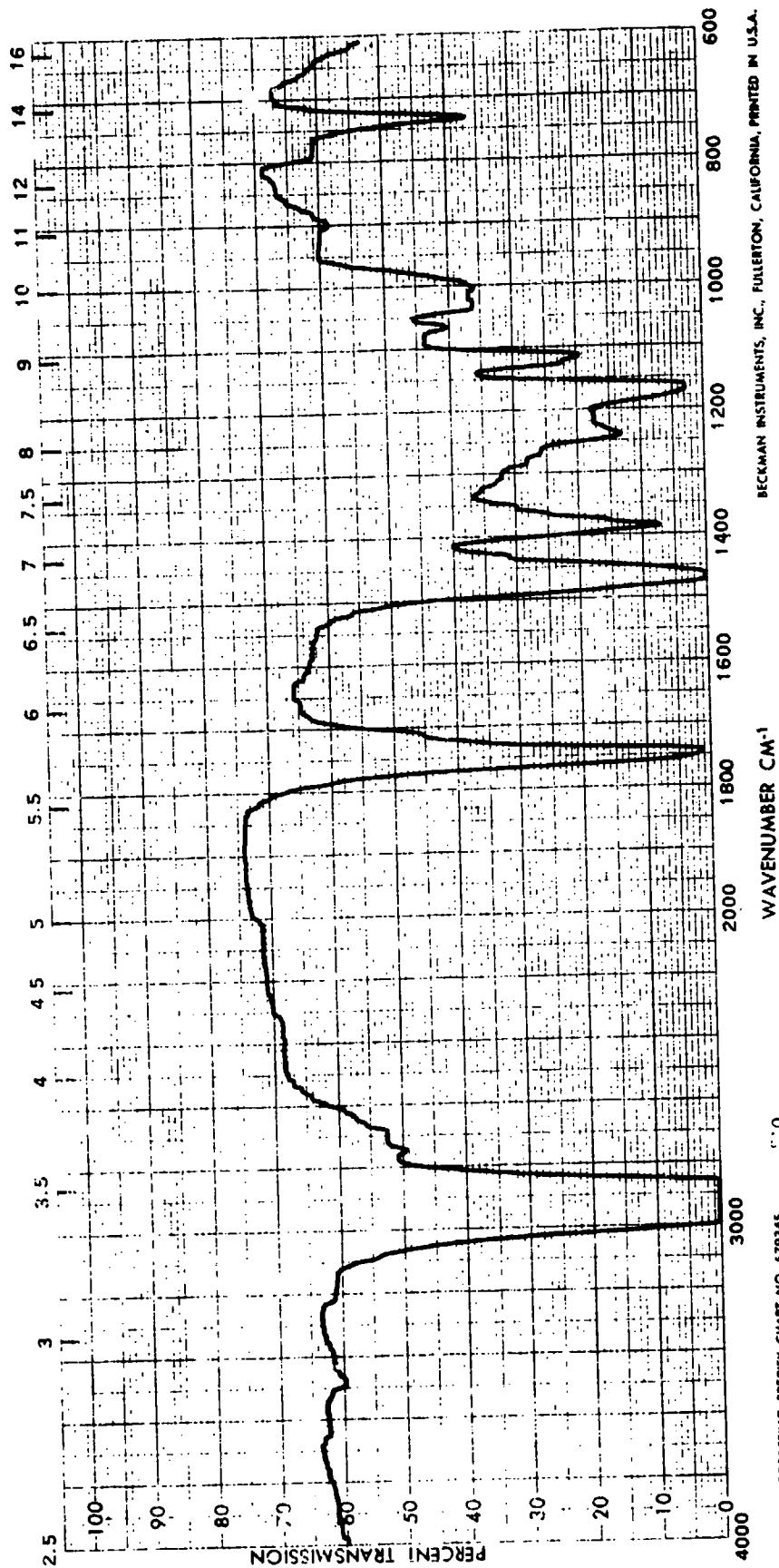


SPECTRUM NO. _____
SAMPLE _____

SPECTRUM NO. 1745	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE AL-8406-L	PURITY _____	1. _____	_____
60 hr	PHASE _____	2. _____	_____
	THICKNESS .025	DATE 10-3-79	_____
		OPERATOR T.W.	_____



SPECTRUM NO. 1746		SPECTRUM NO. _____	
SAMPLE AL-8406-L		SAMPLE _____	
120 hr		1. _____	
PURITY _____		2. _____	
PHASE _____		DATE 10-3-79	
THICKNESS .025		OPERATOR T.W.	
ORIGIN _____		REMARKS _____	
LEGEND _____		_____	



WAVENUMBER CM⁻¹

BECKMAN INSTRUMENTS, INC., FULLERTON, CALIFORNIA, PRINTED IN U.S.A.

WHEN REORDERING SPECIFY CHART NO. 579345

SPECTRUM NO. _____
SAMPLE _____

REMARKS _____

LEGEND _____

ORIGIN _____

SPECTRUM NO. 1747

SAMPLE AL-8406-L

PURITY _____

PHASE _____

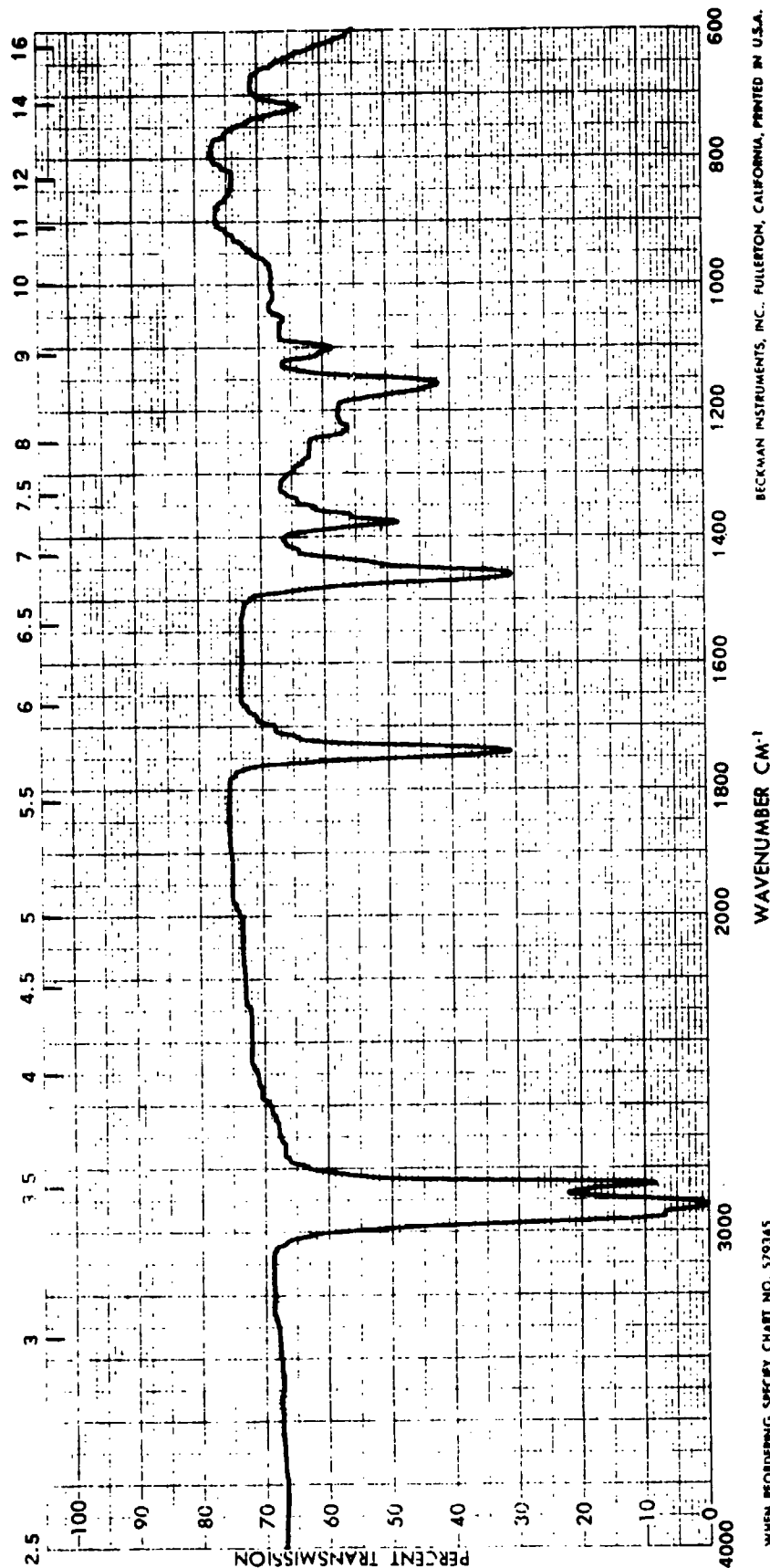
THICKNESS .025

1. _____

2. _____

DATE 10-3-79

OPERATOR T.W.



WHEN REORDERING SPECIFY CHART NO. 579345

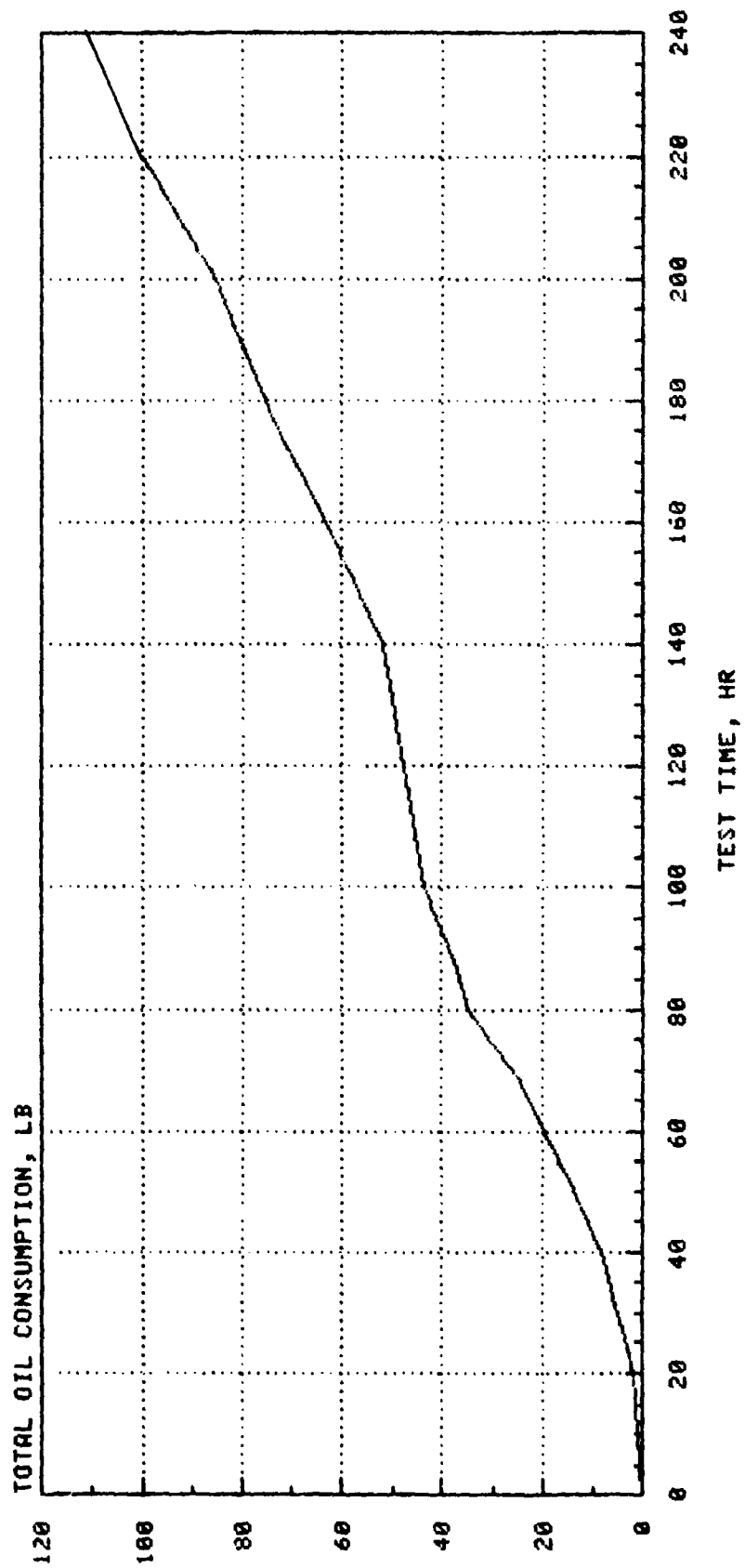
BECKMAN INSTRUMENTS, INC., FULLERTON, CALIFORNIA, PRINTED IN U.S.A.

E-15

SPECTRUM NO. _____
SAMPLE _____

SPECTRUM NO. <u>1748</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-8406-L</u>	PURITY _____	1. _____	
240 hr	PHASE _____	2. _____	
	THICKNESS <u>.025</u>	DATE <u>10-3-79</u>	
		OPERATOR <u>T.W.</u>	

6V53T ENDURANCE TEST-240 HR TRACKED
Test No. CI5136206-7 Lubricant: AL-8406-L



WEAR MEASUREMENTS
 TEST NO.: CI5136206-7
 LUBRICANT: AL-8406-L
 TEST HOURS: 240

Cylinder No.		Cylinder Liner ID, Inches					
		Perpendicular to Crankshaft			Parallel to Crankshaft		
		Top	Middle	Bottom	Top	Middle	Bottom
1L	Before	3.8758	3.8758	3.8758	3.8758	3.8758	3.8760
	After	3.8768	3.8780	3.8764	3.8758	3.8757	3.8764
	Change	0.0010	0.0022	0.0006	0.0000	-0.0001	0.0004
2L	Before	3.8761	3.8761	3.8763	3.8762	3.8762	3.8764
	After	3.8810	3.8793	3.8778	3.8781	3.8772	3.8768
	Change	0.0049	0.0032	0.0015	0.0019	0.0010	0.0004
3L	Before	3.8756	3.8758	3.8759	3.8757	3.8758	3.8761
	After	3.8768	3.8768	3.8769	3.8759	3.8759	3.8768
	Change	0.0012	0.0010	0.0010	0.0002	0.0001	0.0007
1R	Before	3.8758	3.8757	3.8761	3.8754	3.8759	3.8761
	After	3.8763	3.8775	3.8772	3.8759	3.8775	3.8767
	Change	0.0005	0.0018	0.0011	0.0005	0.0016	0.0006
2R	Before	3.8755	3.8761	3.8763	3.8757	3.8761	3.8764
	After	3.8768	3.8764	3.8768	3.8758	3.8759	3.8764
	Change	0.0013	0.0003	0.0005	0.0001	-0.0002	0.0000
3R	Before	3.8758	3.8758	3.8764	3.8764	3.8760	3.8758
	After	3.8772	3.8776	3.8770	3.8757	3.8758	3.8768
	Change	0.0014	0.0018	0.0006	-0.0007	-0.0002	0.0010
Average							
Changes		0.0017	0.0017	0.0009	0.0003	0.0004	0.0005
Overall Average							
Changes		0.0009					

WEAR MEASUREMENTS
ENGINE NO.: 5136206-7
LUBRICANT: AL-8406-L
TEST HOURS: 240

Piston No.	Piston Ring End Gap, inches						
	1	2	3	4	5	6	7
1L Before	0.034	0.033	0.029	0.030	0.021	0.019	0.018
After	0.043	0.030	0.030	0.029	0.034	0.029	0.027
Change	0.009	-0.003	0.001	-0.001	0.013	0.010	0.009
2L Before	0.026	0.030	0.029	0.031	0.021	0.018	0.017
After	0.035	0.030	0.031	0.033	0.032	0.026	0.027
Change	0.009	0.000	0.002	0.002	0.011	0.008	0.010
3L Before	0.027	0.031	0.030	0.028	0.021	0.018	0.017
After	0.029	0.033	0.034	0.028	0.035	0.026	0.026
Change	0.002	0.002	0.004	0.000	0.014	0.008	0.009
1R Before	0.030	0.032	0.033	0.034	0.022	0.018	0.017
After	0.035	0.035	0.032	0.034	0.034	0.026	0.027
Change	0.005	0.003	-0.001	0.000	0.012	0.008	0.010
2R Before	0.035	0.040	0.029	0.030	0.023	0.019	0.020
After	0.037	0.036	0.028	0.031	0.035	0.029	0.030
Change	0.002	-0.004	-0.001	0.001	0.012	0.010	0.010
3R Before	0.031	0.031	0.029	0.037	0.022	0.020	0.018
After	0.037	0.033	0.029	0.038	0.035	0.030	0.028
Change	0.006	0.002	0.000	0.001	0.013	0.010	0.010
Average Change	0.006	0.000	0.001	0.001	0.013	0.009	0.010

RATING DATA SHEET
CI-7

Test Run at AFLRL
Test Lubricant: AL-8406-L
Test Fuel: 1-H CAT
Test No.: CI5136206-7
Test Stand: 5
Engine No.: 6V53T-5136206
Test Hours: 240
Date Started: 15 August 1979
Completed: 31 August 1979

A. Cylinder Liner Ratings

Intake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
1 L	05
2 L	10
3 L	02
1 R	01
2 R	01
3 R	01
Average	03

Scuffing, Glazing and Lacquer*

<u>Cylinder No.</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>Total</u>		
1 L	05	05	05	20	80
2 L	95	75	85	05	95
3 L	15	05	10	10	90
1 R	05	05	05	15	85
2 R	10	10	10	15	85
3 R	10	20	15	20	80
Average	23	20	22	14	86

*Ring Travel Area.

RATING DATA SHEET - CONTINUED
CI-7

B. Piston Ratings

Cylinder No.	<u>Ring Sticking and Condition</u>			
	<u>Ring</u>			
	<u>Fire</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
1 L	F 10%B	F 1%B	F 0%B	F 0%B
2 L	X F 100%B	F 100%B	F 100%B	F 100%B
3 L	F 100%B	F 5%B	F 5%B	F 5%B
1 R	F 30%B	F 0%B	F 0%B	F 0%B
2 R	5%P 15%B	F 0%B	F 0%B	F 0%B
3 R	F 50%B	F 0%B	F 0%B	F 1%B

X = Partially Collapsed

Ring Groove Carbon Filling and Oil Groove Lacquer

Cylinder No.	<u>Groove Filling, %</u>				<u>Oil Groove Lacquer</u>	
	<u>Fire</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>Upper</u>	<u>Lower</u>
1 L	5	75	<1	<1	4	4
2 L	5	90	85	10	4	4
3 L	5	95	5	<1	4	4
1 R	5	45	<1	<1	4	4
2 R	5	60	2	<1	4	4
3 R	5	70	5	<1	4	4

Land Description

<u>Cylinder No.</u>	<u>Description</u>
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Skirt

Cylinder No.	<u>Side</u>	
	<u>Thrust</u>	<u>Anti-Thrust</u>
1 L	6.0 Scratches and Plate Melt	5.8 Scratches and Lt. Scuff
2 L	6.2 Scuff and Plate Melt	6.0 Scuff and Plate Melt
3 L	5.5 Lt. Scratches	6.0 Lt. Scratches
1 R	6.0 Lt. Scratches	5.7 Lt. Scratches
2 R	6.0 Lt. Scratches	5.5 Lt. Scratches
3 R	5.5 Lt. Scratches and Lt. Scuff	6.2 Lt. Scratches

RATING DATA SHEET - CONTINUED
CI-7

C. Other Ratings

Combustion Chambers

<u>Cylinder No.</u>	<u>Description</u>	<u>Cylinder No.</u>	<u>Description</u>
1 L	50% AHC	1 R	35% AHC
2 L	30% AHC	2 R	10% 60% AHC
3 L	35% AHC	3 R	80% AHC

Valve Covers, Oil Pan and Cylinder Head Deck

Covers	½ A Sludge
Pan	½ A Sludge
Deck	½ A Sludge

Remarks

The No. 2 Left Injector cam lobe and roller failed.
Nos. 2, 3 and 4 Main Bearings have some deep scratches and journals are a little rough.
No. 3-Right Cam Bearing spun on shaft and damaged shaft and maybe bore in block.

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-8406-L

RATER E. Lyons DATE 9-11-79
 LABORATORY TEST NUMBER 7
 STAND NO. 5 ENGINE NO. 6V55T-5136206
 FUEL CAT I-H

PISTON NO. 1-Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME %	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD * RATING	
		AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT	AREA %	DEMERIT
CARBON	HC 1.00									100	100.00	50	50.00						
	MHC 0.75																		
	MC 0.50			70	35.00							30	15.00						
	LC 0.25	100	25.00	30	7.50							20	5.00						
	VLC 0.15																		
CARBON RATING		25.00		42.50						100.00		70.00							
LACQUER	BL 0.100													5	0.50				
	DBrL 0.075																	100	7.50
	AL 0.050					100	5.00							95	4.75				
	LAL 0.025							100	2.50							100	2.50		
	VLAL 0.010																		
LACQUER RATING						5.00		2.50						5.25		2.50		7.50	
CLEAN 0																			
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		25.00		42.50		5.00		2.50		100.00		70.00		5.25		2.50		7.50	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AT-8406-L

RATER E. Lyons DATE 9-11-79
 LABORATORY TEST NUMBER 7
 STAND NO 5 ENGINE NO. 6V53T-5136206
 FUEL CAT 1-H

PISTON NO. 2-Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN		
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1 GROOVE, VOLUME-%	PISTON WTD* RATING	276.50
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT			
CARBON																				
HC	1.00			45	45.00					100	100.00	35	35.00							
MHC	0.75											35	17.50							
MC	0.50			30	15.00							30	7.50	10	2.50					
LC	0.25	100	25.00	25	6.25															
VLC	0.15																			
CARBON RATING		25.00		66.25						100.00		60.00		2.50						
BL	0.100													10	1.00			100	7.50	
DBrL	0.075																			
AL	0.050					100	5.00							80	4.00	10	0.50			
LAL	0.025															90	2.25			
VLAL	0.010																			
RL	0.001																			
LACQUER RATING						5.00		2.50						5.00		2.75				
CLEAN	0																			
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING		25.00		66.25		5.00		2.50		100.00		60.00		7.50		2.75				

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-8406-L

RATER E. Lyons DATE 9-11-79
 LABORATORY TEST NUMBER 7
 STAND NO. 5 ENGINE NO. 6V53T-5136206
 FUEL CAT 1-H

PISTON NO. 3-Right

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		AREA-%	DEMERIT
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC									50	50.00	15	15.00						
	MHC			70	52.50														
	MC	20	10.00	10	5.00					50	25.00	70	35.00	5	2.50				
	LC	80	20.00	20	5.00	100	25.00					15	3.75	95	23.75				
	VLC																		
CARBON RATING		30.00		62.50		25.00				75.00		53.75		26.25					
LACQUER	BL																		
	DBrL																	100	7.50
	AL															30	1.50		
	LAL							100	2.50							70	1.75		
	VLAL																		
	RL																		
LACQUER RATING								2.50								3.25		7.50	
CLEAN																			
ZONAL RATING																			
LOCATION FACTOR										75.00		53.75		26.25		3.25			
WEIGHTED RATING		30.00		62.50		25.00		2.50										7.50	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFLRL
 LUBRICANT AL-8406-L

RATER E. Lyons DATE 9-11-79
 LABORATORY TEST NUMBER 7
 STAND NO. 5 ENGINE NO. 6V53T-5136206
 FUEL CAT 1-H

PISTON NO. 1-Left

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES										LANDS						NO. 1 GROOVE, VOLUME-%	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4		PISTON WTD* RATING	
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00		10	10.00					90	90.00	90	90.00						
	MHC	0.75		90	67.50														
	MC	0.50												20	10.00				
	LC	0.25				5	1.25			10	2.50	10	2.50	10	2.50				
	VLC	0.15	100	15.00															
CARBON RATING		15.00		77.50		1.25				92.50		92.50		12.50					
LACQUER	BL	0.100												25	2.50	5	0.50		
	DBrL	0.075				95	7.125											100	7.50
	AL	0.050												45	2.25				
	LAL	0.025						100	2.50							95	2.375		
	VLAL	0.010																	
LACQUER RATING						7.125								5.00					
CLEAN		0																	
ZONAL RATING																		2.875	
LOCATION FACTOR										92.50									
WEIGHTED RATING		15.00		77.50		8.375		2.50		92.50		92.50		17.50		2.875			7.50

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Tracked cycle
 TEST HOURS 240
 TEST LABORATORY AFRL
 LUBRICANT AL-8406-L

RATER E. Lyons DATE 9-11-79
 LABORATORY TEST NUMBER 7
 STAND NO. 5 ENGINE NO. 6V53T-5136206
 FUEL CAT I-H

PISTON NO. 2-Left

LUBRICANT		FUEL CAT 1-H		NO. 1 GROOVE, VOLUME-%		PISTON WTD* RATING		391.25	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 3-Left

TEST PROCEDURE Tracked cycle

TEST HOURS 240

TEST LABORATORY FLkL

LUBRICANT AL-8406-L

RATER E. Lyons DATE 9-11-79

LABORATORY TEST NUMBER 7

STAND NO. 5 ENGINE NO. 6V53T-5136206

FUEL CAT J-H

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	324.25

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		
CARBON	HC	1.00		100	100.00									90	90.00				
	MHC	0.75																	
	MC	0.50								100	50.00					5	2.50		
	LC	0.25	100	25.00		20	5.00						10	2.50	95	23.75			
	VLC	0.15																	
CARBON RATING			25.00	100.00		5.00				50.00		92.50		25.25					
LACQUER	BL	0.100				80	80.00												
	DBrL	0.075						100	7.50									100	7.50
	AL	0.050																	
	LAL	0.025															100	2.50	
	VVAL	0.010																	
LACQUER RATING						4.00		7.50									2.50		
CLEAN		0																	
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING			25.00	100.00		13.00		7.50		50.00		92.50		26.25		2.50		7.50	

*WEIGHTED TOTAL DEPOSITS

RING STICKING

Test No. 7

Engine Model 6V53T Serial No. 5136206 Date 9-11-79
 Fuel CAT 1-H Lubricant AL-8406-L Observer E. Lyons

Ring No.	Piston Number					
	1L	2L	3L	1R	2R	3R
1	F	Partially Collapsed	F	F	5%P	F
2	F	F	F	F	F	F
3	F	F	F	F	F	F
4	F	F	F	F	F	F

Indicate by letter — Free or Sluggish, or by number and letter — percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

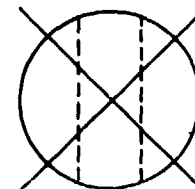
PISTON GROOVE INSIDE DIAMETER-% RING SUPPORTING CARBON

Test No. 7

Engine Model! 6V53T Serial No. 5136206 Date 9-11-79
 Fuel CAT 1-H Lubricant AL-8406-L Observer E. Lyons

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	5	0	10	5	10	0
	2	40	0	90	0	80	15
	3	0	0	95	0	15	5
	4	0	0	100	0	0	0

1 Thrust Side



4 Front

2 Rear

3 Anti-Thrust Side

VALVE DEPOSITS

Engine Model 6V53T Test No. 7 Date 9-11-79
 Serial No. 5136206
 Fuel CAT 1-H Lubricant AL-E406-L Observer E. Lyons

Cylinder Number																					
Head*	1L			2L			3L			1R			2R			3R					
	CARB	LACQ		CARB	LACQ		CARB	LACQ		CARB	LACQ		CARB	LACQ		CARB	LACQ				
	INT	A	L	A	H	C															
Face	EXH																				
	INT	N	O.	9	L	A	C	Q	U	E	R										
Tulipt	EXH																				
	INT	N	O.	9	L	A	C	Q	U	E	R	&	L	I	C	H	A	R	B	O	N
Stem	EXH																				
	INT	N	O.	9	L	A	C	Q	U	E	R	T	O	C	L	E	A	N			
	EXH																				

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S, (Page 5).

Lacquer: Pages 4, 36 and 37.

EXHAUST VALVE SURFACE CONDITIONS

Test No. 7

Engine Model 6V53T Serial No. 5136206 Date 9-11-79

Fuel CAT 1-H Lubricant AL-8406-L Observer E. Lyons

	1L	2L	3L	1R	2R	3R
Freeness in Guide	F	F	F	F	F	F
Head	N	N	N	N	N	N
Face	A F E W L I G H T P I T S					
Seat	N	N	N	N	N	N
Stem	N	N	N	N	N	N
Tip	N	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

F = FREE
N = NORMAL

TAPPETS, CAMS, AND ROCKER ARMS

Test No. 7

Date 9-11-79

Serial No. 5136206

6V53T

Engine Model

Observer E. Lyons

Lubricant AL-8406-L

Fuel CAT 1-H

Cylinder Number									
	1L	2L	3L	1R	2R	3R			
Tappet Deposit	INT								
	EXH								
	INJ								
Tappet Surface Condition	INT								
	EXH								
Cam Lobes									
Rocker Arms	Tip	INT							
		EXH							
	Bushing	INT							
		EXH							
	Shaft	INT							
		EXH							

Lacquer: Pages 4, 36 and 37 of Manual.
See Pages 1, 2, 16 through 23, and 54 through 65.

SURFACE CONDITION

Test No. 7

Engine Model 6V53T Serial No. 5136206 Date 9-11-79
 Fuel CAT 1-H Lubricant AL-8406-L Observer E. Lyons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing	Lt. Scratches	Copper Showing	Scratched Babbit (Goen)	Copper Showing			
	N	SOME ROUGH SPOTS					
Rod-Bearing	ALL HAVE SOME SCRATCHES AND NORMAL WEAR PATTERNS						
	N	N	N	N	N	N	
Piston Pin	N	N	N	N	N	N	
Bushing	N	N	N	N	N	N	

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

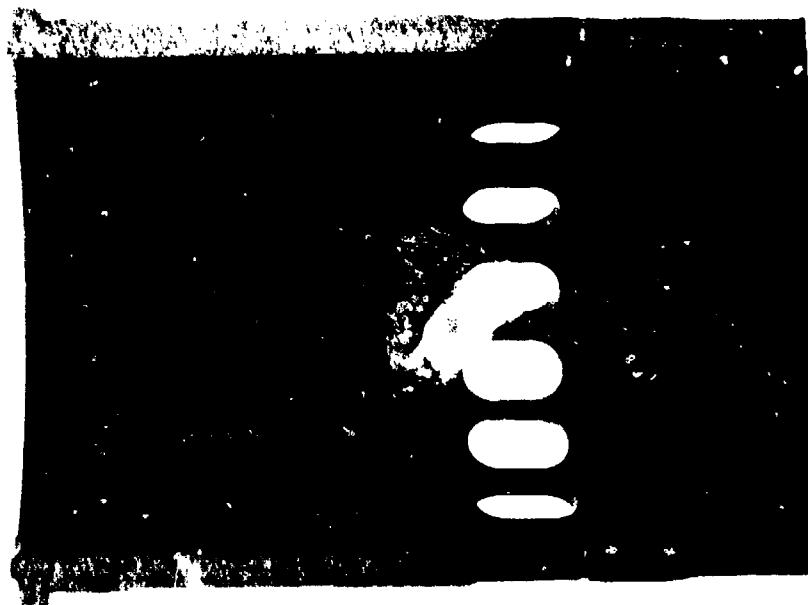
N = NORMAL

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



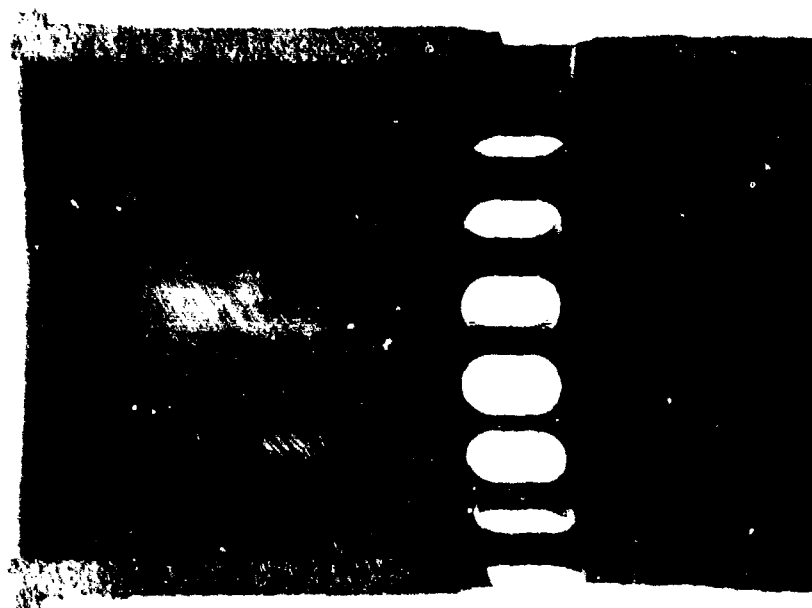
1-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



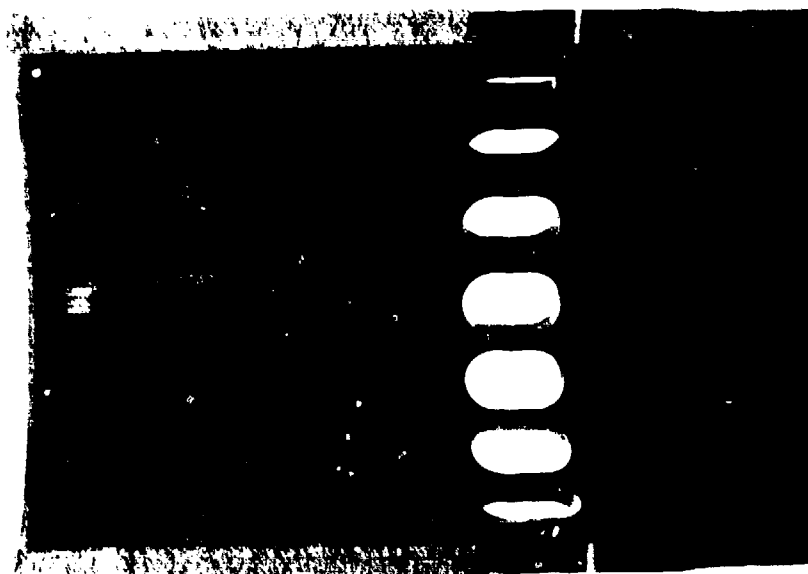
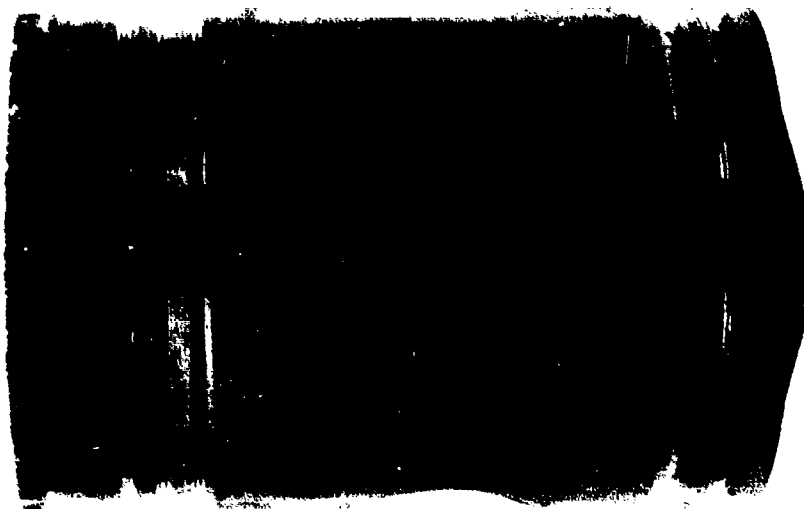
1-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



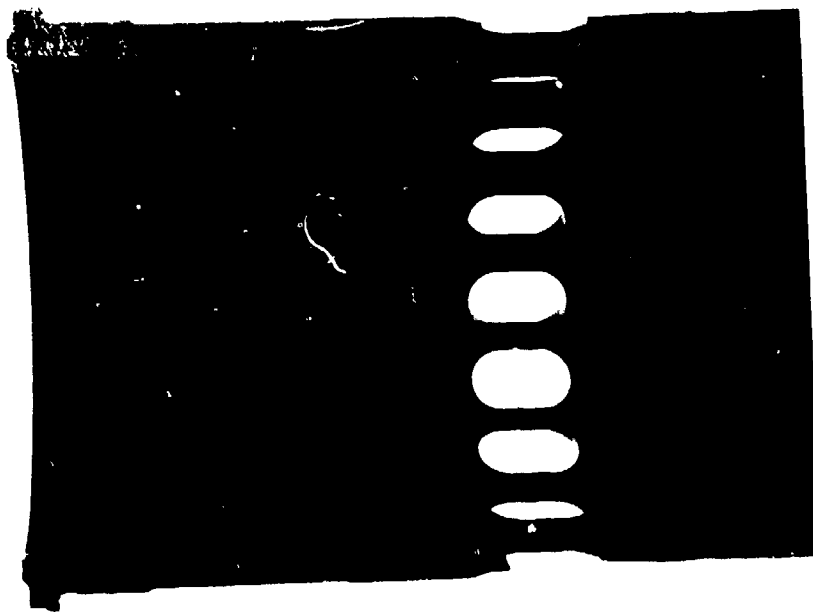
2-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



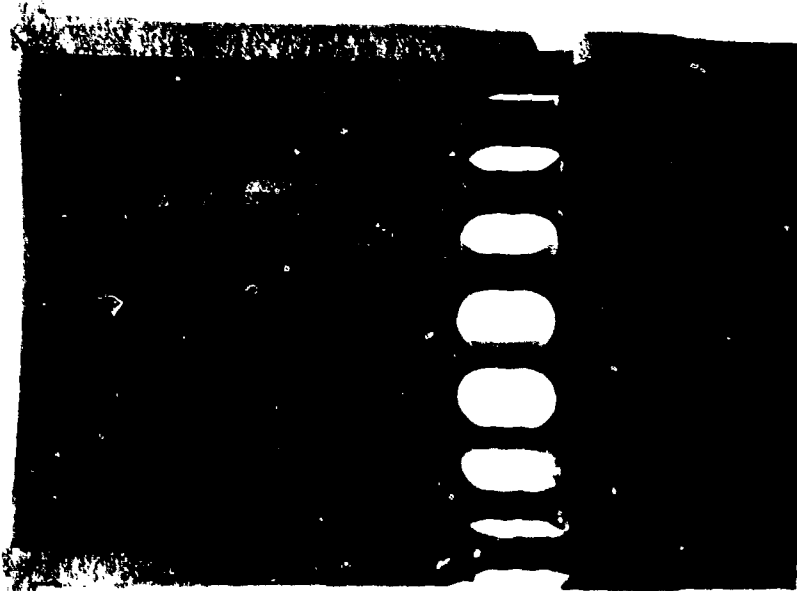
2-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST HOURS: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



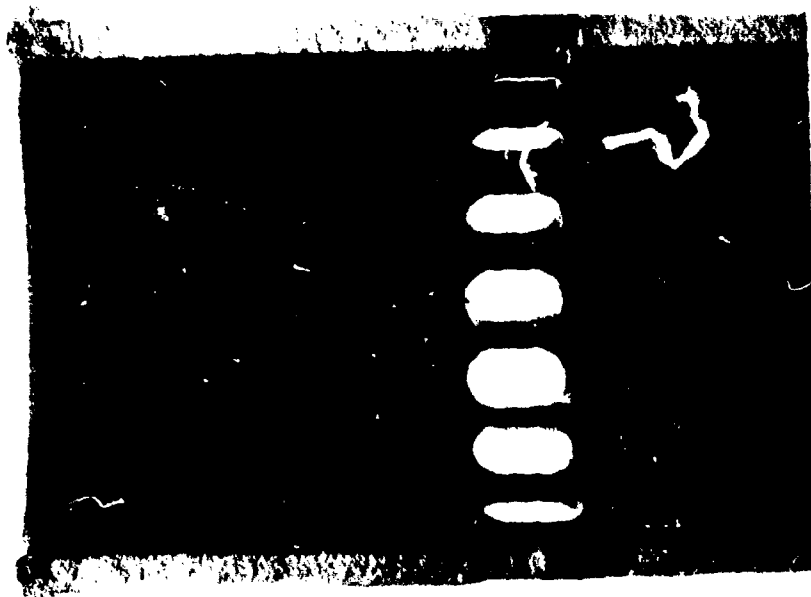
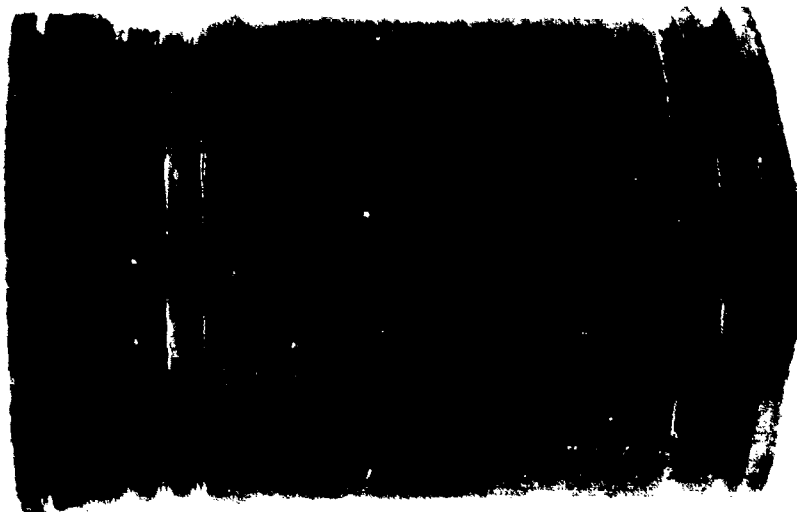
3-RIGHT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



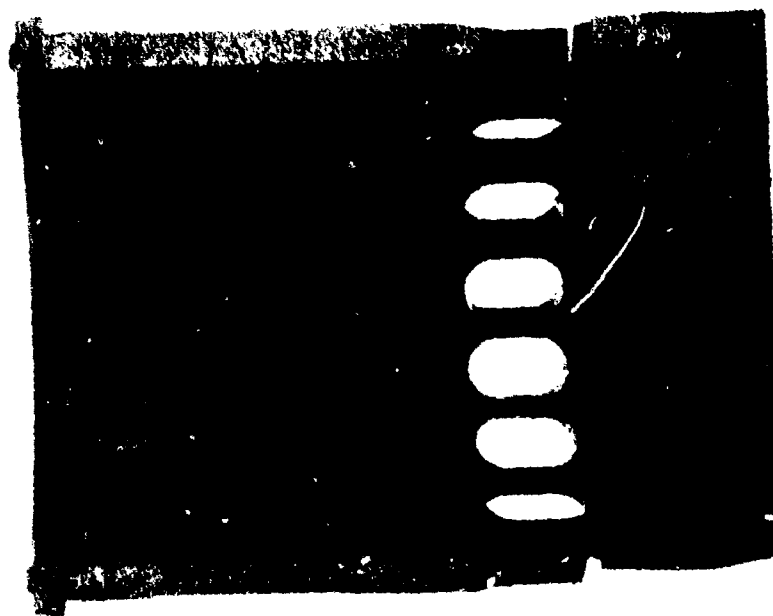
3-RIGHT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



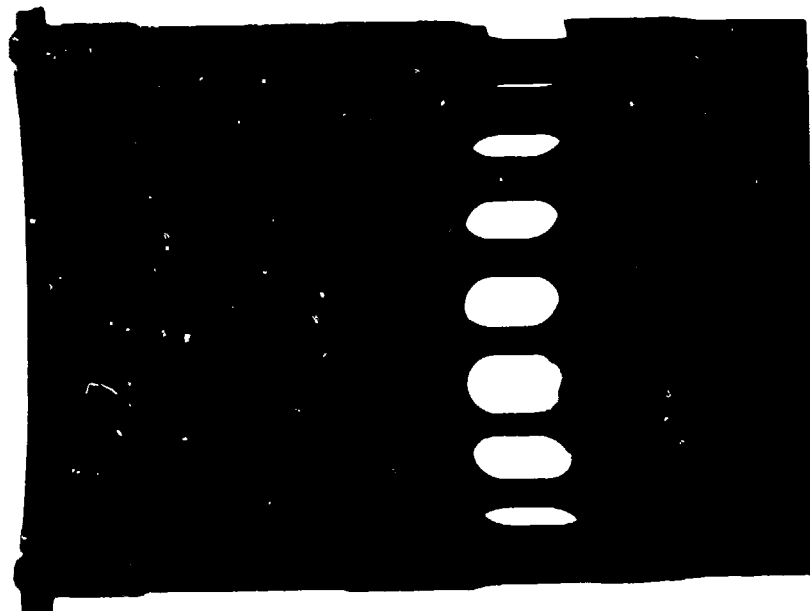
1-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



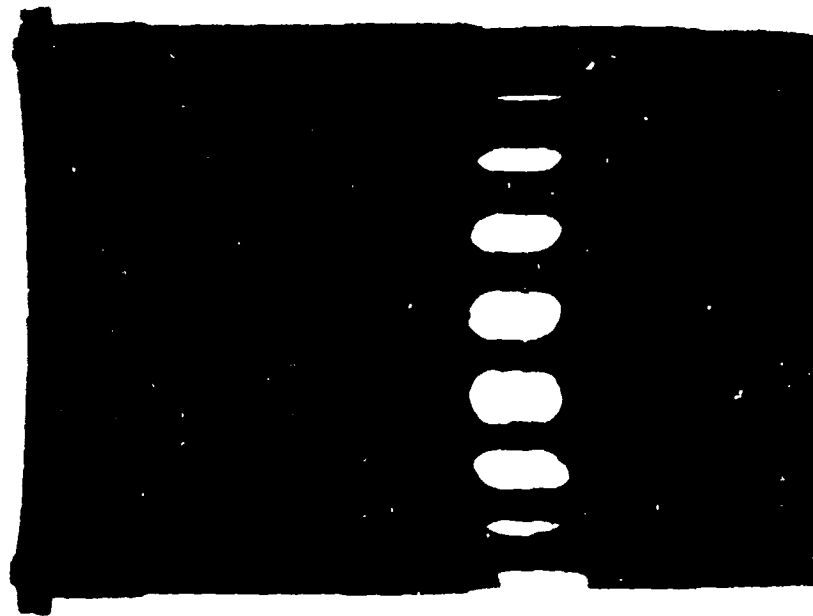
1-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



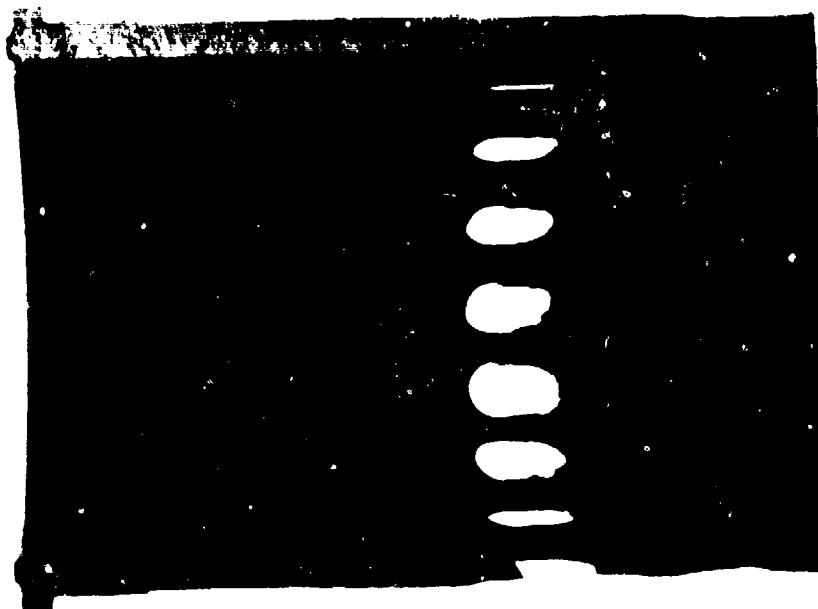
2-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



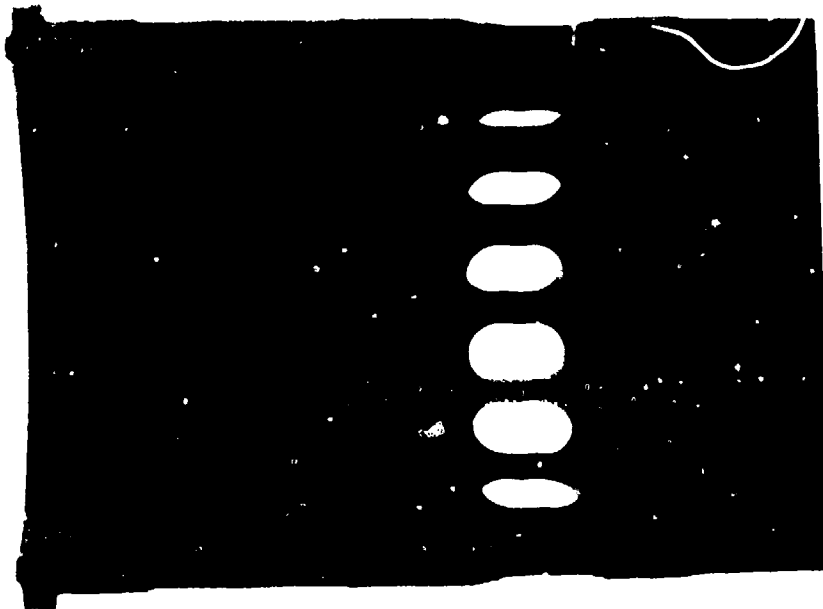
2-LEFT ANTI-THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



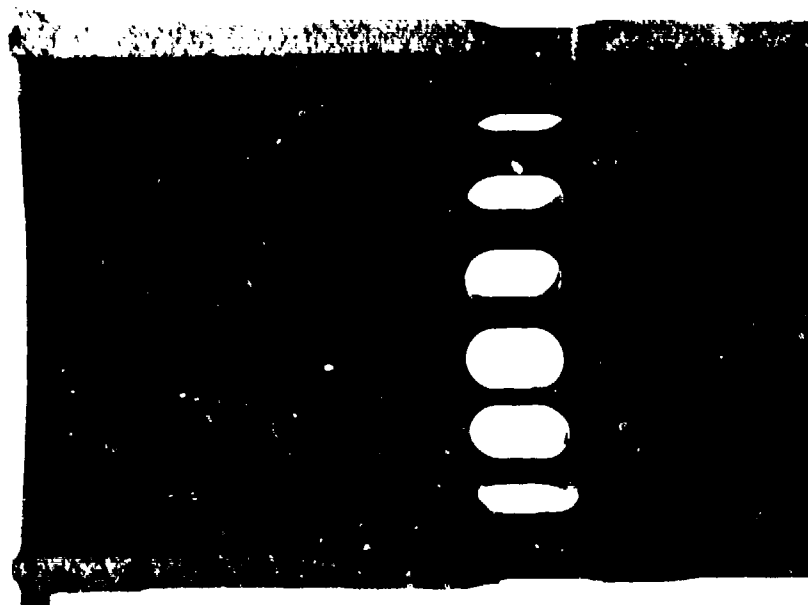
3-LEFT THRUST

CONDITION OF PISTON AND CYLINDER LINER

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



3-LEFT ANTI-THRUST

CONDITION OF PISTON RING FACE

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



1-RIGHT



2-RIGHT



3-RIGHT

CONDITION OF PISTON RING FACE

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



1-LEFT



2-LEFT



3-LEFT

CONDITION OF CYLINDER HEADS

TEST TIME: 240 HOURS

TEST: 7

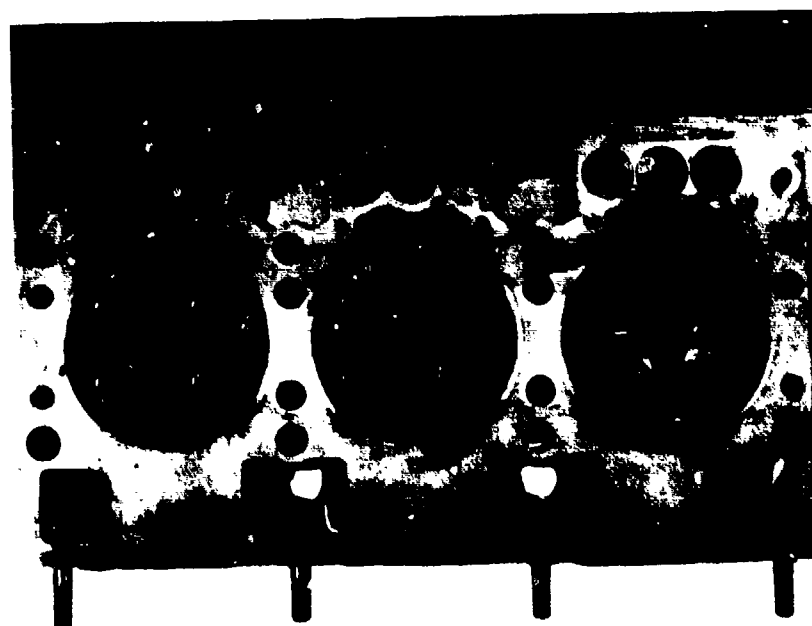
LUBRICANT: AL-8406-L



3L

2L

1L



1R

2R

3R

CONDITION OF ROD BEARINGS

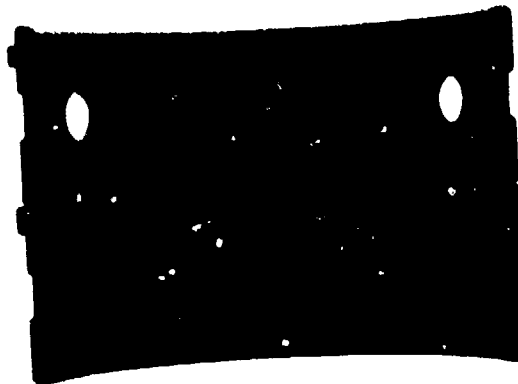
TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



1-RIGHT



2-RIGHT



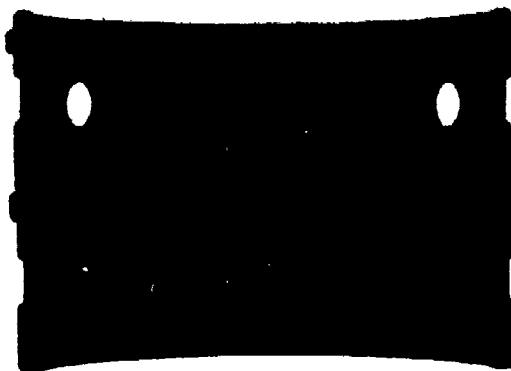
3-RIGHT

CONDITION OF ROD BEARINGS

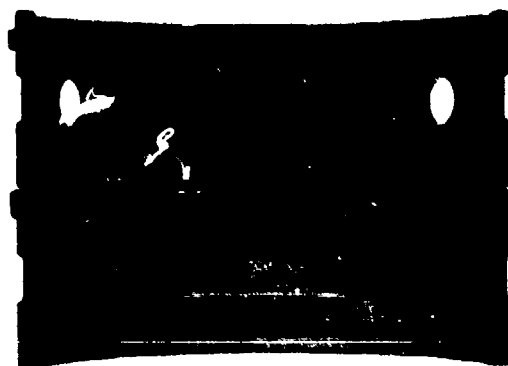
TEST TIME: 240 HOURS

TEST: 7

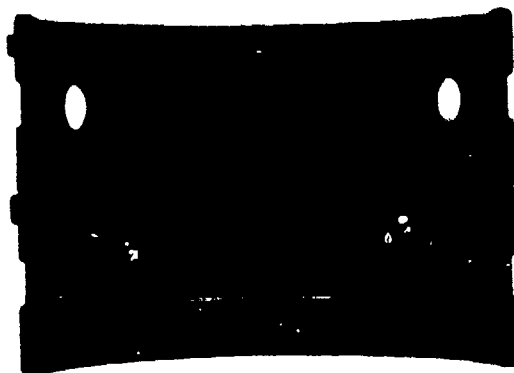
LUBRICANT: AL-8406-L



1-LEFT



2-LEFT



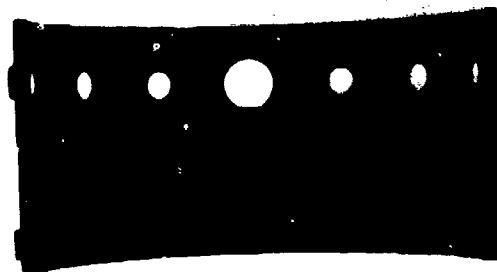
3-LEFT

CONDITION OF MAIN BEARINGS

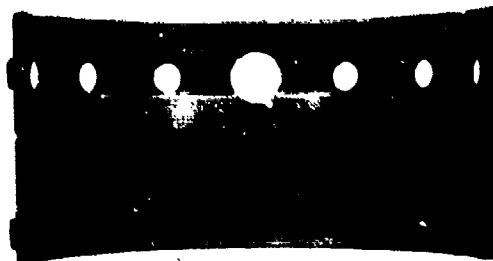
TEST TIME: 240 HOURS

TEST: 7

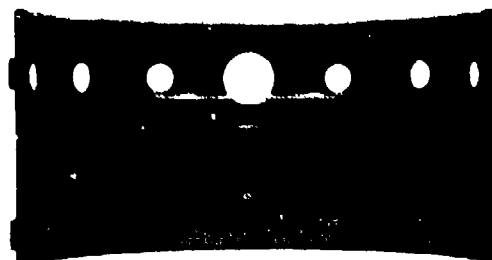
LUBRICANT: AL-8406-L



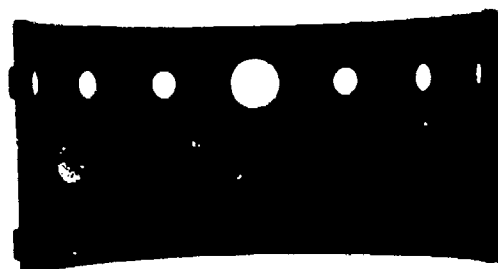
No. 1



No. 2



No. 3



No. 4

CONDITION OF NO. 2 LEFT FUEL INJECTION CAM FOLLOWER AND CAM LOBE

TEST TIME: 240 HOURS

TEST: 7

LUBRICANT: AL-8406-L



CAM FOLLOWER



CAM LOBE

APPENDIX F

ENGINE-LUBRICANT COMPATIBILITY TEST #8
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

Test Lubricant: AL-7172-1
Test Fuel: Caterpillar 1-H
Engine Test Number: 8
Date Completed: 14 May 1980

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

by

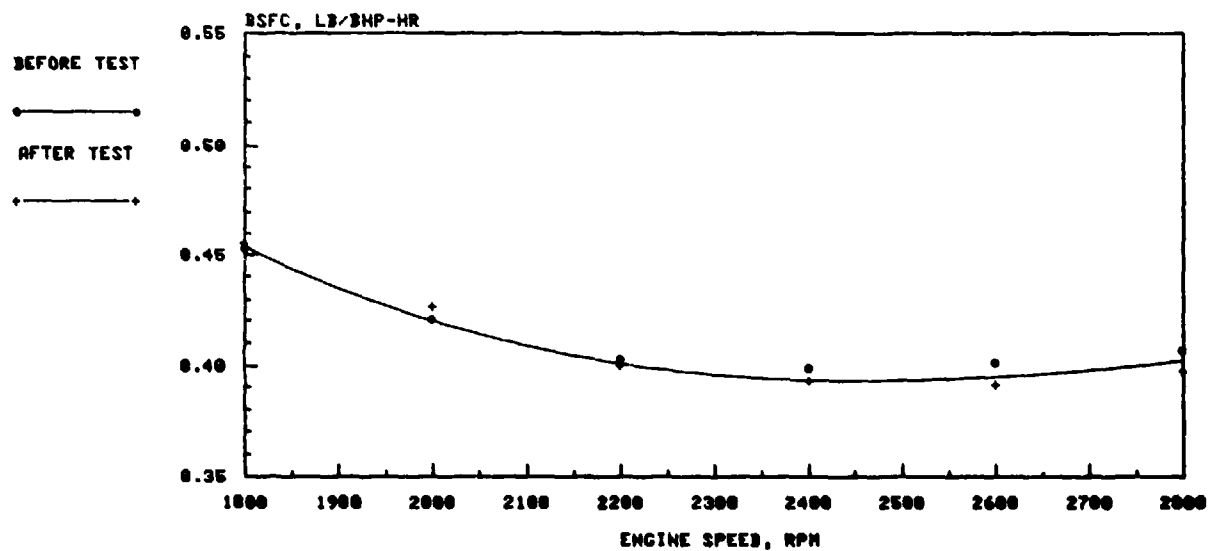
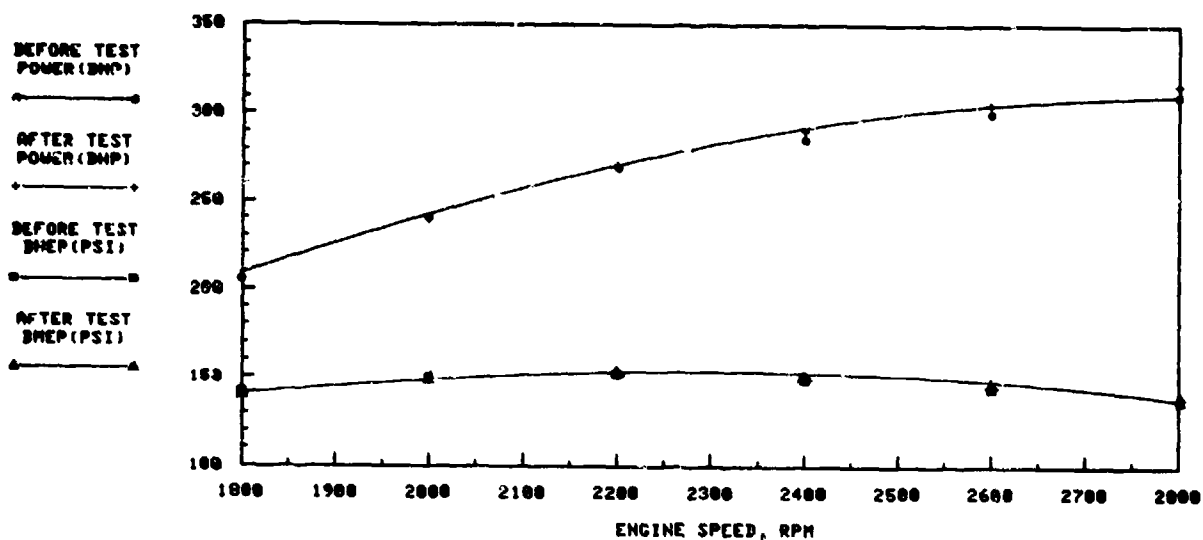
U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V53T
TEST 8
ENGINE REBUILD MEASUREMENTS
Model Number: 5063-5397
Serial Number: 6D-178671

	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Specified Limits*</u>
<u>Cylinder Block Bore</u>				
Inside Diameter (bottom)	4.3563	4.3573	4.3571	4.3595 max
Out-of-Round	0.0001	0.0010	0.0003	0.0015 max
Taper	0.0001	0.0004	0.0002	0.0015 max
<u>Cylinder Liners (installed)</u>				
Inside Diameter	3.8750	3.8761	3.8755	3.8752-3.8767
Out-of-Round	0.0000	0.0004	0.0002	0.0020 max
Taper	0.0001	0.0009	0.0004	0.0010 max
Piston Diameter (@ skirt)	3.8673	3.8679	3.8676	3.8669-3.8691
Piston Skirt to Cylinder Liner Clearance	0.0073	0.0089	0.0079	0.0061-0.0098
<u>Compression Rings</u>				
Gap (Fire)	0.032	0.036	0.034	0.020-0.046
Gap (others)	0.025	0.036	0.028	0.020-0.036
Ring-to-Groove Clearance				
Top (Fire)	0.003	0.004	0.004	0.003-0.006
No. 1	0.007	0.008	0.008	0.007-0.010
No. 2 and No. 3	0.006	0.007	0.007	0.005-0.008
<u>Oil Control Rings</u>				
Gap	0.018	0.021	0.020	0.010-0.025
Ring-to-Groove Clearance	0.002	0.003	0.003	0.0015-0.0055
Connecting Rod Bearing- to-Journal Clearance	0.0024	0.0033	0.0026	0.0011-0.0041
Main Bearing-to-Journal Clearance	0.0040	0.0042	0.0041	0.0011-0.0041
Camshaft Bearing-to- Shaft Clearance	0.0047	0.0051	0.0049	0.0045-0.0060

*All measurements are in inches.

6V-53T 240 HOUR TRACKED VEHICLE CYCLE BEFORE AND AFTER TEST 8 PERFORMANCE DATA



6V-53T
240 HOUR TRACKED VEHICLE CYCLE ENDURANCE TEST
TEST 8
OPERATING CONDITIONS SUMMARY
Lubricant: AL-7172-L Fuel: Caterpillar 1-H

	Maximum Power Mode (2800 rpm)		Maximum Torque Mode (2200 rpm)	
	Mean	Standard* Deviation	Mean	Standard Deviation
Engine Speed, rpm	2805	2	2206	3
Torque, Ft-lb (N-m)	567(769)	14(19)	635(861)	9(12)
Fuel Consumption, lb/hr (kg/hr)	121.3(55.07)	2.6(1.18)	105.8(48.03)	1.3(0.59)
Observed Power, Bhp (kW)	303(226)	6(4)	267(199)	4(3)
BSFC, lb/Bhp-hr (g/kW-hr)	.400(243)	0.002(1)	.396(241)	0.003(2)
<u>Temperatures, °F (°C)</u>				
Exhaust before turbo	1031(554)	20(11)	1071(577)	26(14)
Exhaust after turbo	866(463)	14(8)	902(483)	12(7)
Water Jacket Inlet	155(68)	1(1)	155(68)	1(1)
Water Jacket Outlet	170(77)	1(1)	170(77)	1(1)
Oil Sump	237(114)	2(1)	229(109)	2(1)
Fuel at Filter	94(34)	3(2)	92(33)	2(1)
Inlet Air (at compressor)	95(35)	6(3)	93(34)	5(3)
Airbox	293(145)	8(4)	241(116)	5(3)
<u>Pressures</u>				
Exhaust before turbo, psi (kPa)	14.9(103)	0.3(2)	10.1(70)	0.3(2)
Exhaust after turbo, in. Hg(kPa)	2.8(9.5)	0.1(0.3)	1.8(6.1)	0.1(.3)
Compressor Discharge, psi (kPa)	14.6(101)	0.4(3)	11.0(76)	0.3(2)
Blower Discharge, psi (kPa)	19.6(135)	0.5(3)	12.2(84)	0.4(3)
Oil Gallery, psi (kPa)	57(393)	1(7)	46(317)	1(7)
Intake Vacuum, in. H ₂ O (Pa)	7.6(1890)	0.2(50)	4.7(1170)	0.1(20)
<u>Ambient Conditions (both modes of operation)</u>				
Dry Bulb Temperature, °F (°C)	78(26)	5(3)		
Wet Bulb Temperature, °F (°C)	73(23)	4(2)		
Barometric Pressure, in. Hg (kPa)	28.87(97.87)	0.23(0.78)		

*68% of the values for a given variable occur within ± 1 standard deviation of the mean;
95% occur within ± 2 standard deviations.

6V-53T
TEST 8
LUBRICANT ANALYSIS

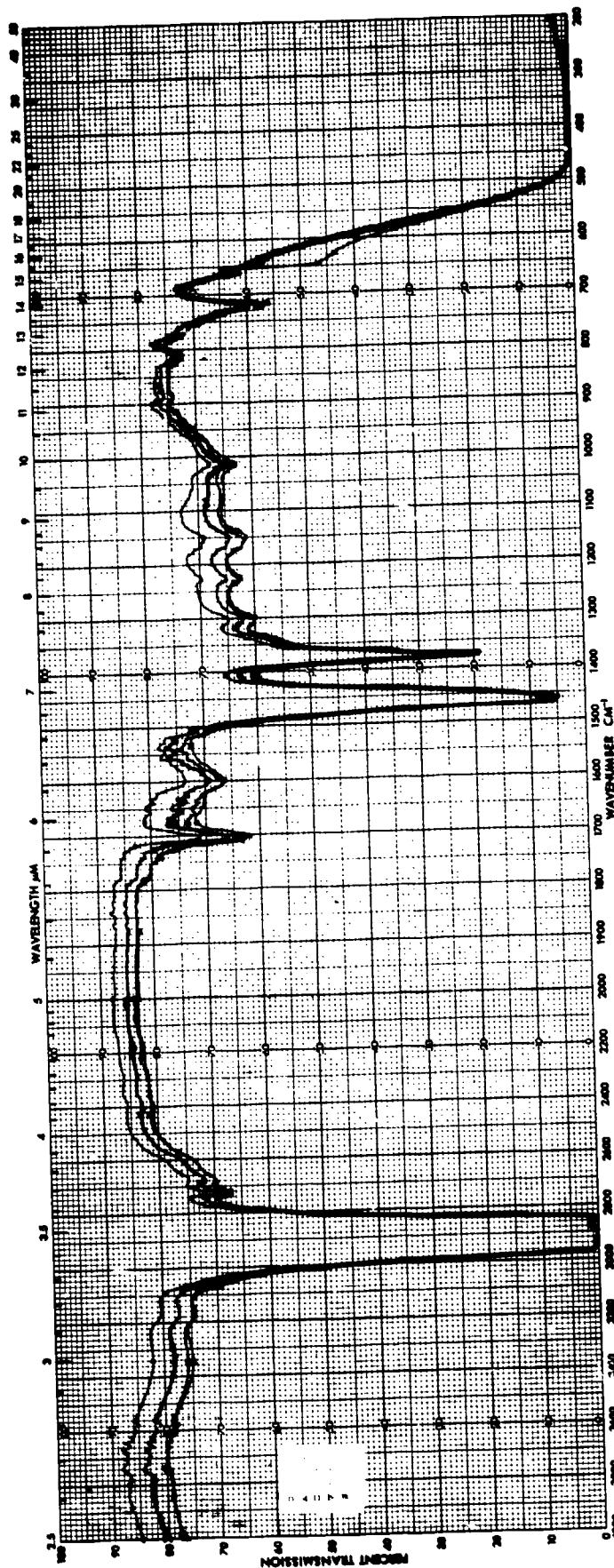
Lubricant: AL-7172-L

	ASTM Test Method	Test Time, Hours				
		0	60	120	180	240
Apparent Viscosity at -29°C (-20°F), cP	D 2602	22770	39580	43950	39580	39580
Apparent Viscosity at -18°C (0°F), cP	D 2602	4150	6380	6940	6380	6710
Kinematic Viscosity at 40° (104°F), cSt	D 445	112.8	112.5	116.8	111.9	115.3
Kinematic Viscosity at 100°C (212°F), cSt	D 445	14.8	13.9	14.2	14.0	13.7
Viscosity Index	D 2270	135	124	122	125	117
Total Acid Number, mg KOH/g	D 664	1.9	2.4	2.9	2.9	3.5
Total Base Number, mg KOH/g	D 664	8.2	5.9	6.4	6.5	6.4
Pentane B Insolubles, wt%	D 893	0.02	0.04	0.11	0.05	0.06
Toluene B Insolubles, wt%	D 893	0.01	0.04	0.09	0.05	0.05
Flash Point, °C (°F)	D 92	210(410)	222(432)	228(442)	220(423)	222(432)
Density at 16°C (60°F), gm/ml	D 287	0.885	0.891	0.893	0.886	0.893
Carbon Residue, wt %	D 524	1.3	1.6	1.8	1.8	1.9
Sulfated Ash, wt %	D 874	1.0	1.2	1.3	1.1	1.3

6V-53T

TEST 8

Lubricant: AL-7172-L



6V-53T
TEST 8
Lubricant: AL-7172-L

TOTAL OIL CONSUMPTION AND WEAR METALS BY XRF

Test Time, Hours	Total Oil Consumed, lb (kg)	Wear Metals, ⁺ ppm	
		Fe(Iron)	Cu(Copper)
20	13.6(6.17)	46	20
33	19.1(8.66)	- ⁺⁺	-
40	29.1(13.20)	53	18
53	33.3(15.10)	-	-
60	42.5(19.28)	67	19
75.5	48.1(21.82)	-	-
80	56.3(25.54)	70	23
95.5	61.5(27.90)	-	-
100	67.4(30.57)	62	21
112.5	74.2(33.66)	-	-
120	86.9(39.42)	71	24
133	92.7(42.05)	-	-
140	100.0(45.36)	33	ND*
145.5	107.4(48.72)	-	-
155.5	112.0(50.80)	-	-
160	115.4(52.34)	39	16
170.5	122.6(55.61)	-	-
180	125.4(56.88)	41	ND
190	132.9(60.28)	-	-
195	138.5(62.82)	-	-
200	139.6(63.32)	35	ND
210	146.7(66.54)	-	-
220	150.9(68.45)	53	ND
230	161.7(73.35)	-	-
240	173.8(78.83)	56	20

Average Oil Consumption Rate: 0.72 lb/hr (0.33 kg/hr)

⁺No other wear metals detected.

⁺⁺Oil samples for wear metal analysis not taken at these times.

*Not Detected.

6V-52T
TEST 8
Lubricant: AL-7172-L

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

	<u>Cylinder Number</u>					
	<u>1L</u>		<u>2L</u>		<u>3L</u>	
	<u>T-AT**</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>
Top	+0.0012	+0.0004	+0.0014	+0.0006	+0.0024	+0.0008
Middle	+0.0014	+0.0011	+0.0017	+0.0021	+0.0010	+0.0014
Bottom	+0.0009	+0.0008	+0.0008	+0.0009	+0.0005	+0.0007

	<u>Cylinder Number</u>					
	<u>1R</u>		<u>2R</u>		<u>3R</u>	
	<u>T-AT</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>
Top	+0.0013	+0.0009	+0.0010	+0.0010	+0.0016	+0.0008
Middle	+0.0012	+0.0014	+0.0017	+0.0006	+0.0017	+0.0014
Bottom	+0.0005	+0.0008	+0.0012	+0.0007	+0.0009	+0.0004

	<u>Average Change</u>	
	<u>T-AT</u>	<u>F-B</u>
	Top	+0.0015 +0.0008
Middle	+0.0015	+0.0013
Bottom	+0.0008	+0.0007

Overall Average Change: +0.0011 inches.

<u>Ring Number</u>	<u>Piston Ring End Gap Change</u>						<u>Average Change</u>
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	
1	+0.001	+0.002	+0.006	+0.001	+0.001	+0.001	+0.002
2	0.000	+0.001	+0.002	+0.002	+0.001	0.000	+0.001
3	+0.001	+0.002	0.000	+0.001	+0.001	0.000	+0.001
4	0.000	0.000	+0.001	0.000	0.000	0.000	0.000
5	+0.007	+0.006	+0.006	+0.007	+0.006	+0.008	+0.007
6	+0.006	+0.006	+0.007	+0.007	+0.008	+0.007	+0.007
7	+0.004	+0.007	+0.005	+0.007	+0.003	+0.004	+0.005

Overall Average Change: +0.003.

*All dimensions given are in inches.

**T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction.

6V-53T
TEST 8
Lubricant: AL-7172-L

POST TEST ENGINE CONDITION AND DEPOSITS

A. Cylinder Liner

	<u>Cylinder Number</u>						<u>Average</u>
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	
Intake Port Plugging, % restriction	1	1	1	1	1	1	1
<u>Liner Scuffing, % Area</u>							
Thrust	15	5	5	5	10	30	12
Anti-Thrust	40	0	2	3	10	10	11
Total	28	3	4	4	10	20	11
						Overall:	11
Liner Glazed, % Area	5	5	10	10	15	10	9
Liner Lacquer, % Area	65	65	80	70	85	65	72

B. Pistons

<u>Ring Face Burn, % Area</u>							
Fire Ring	2	12	65	1	6	5	15
No. 1	1	0	85	1	20	12	20
No. 2	0	0	60	1	7	8	13
No. 3	0	0	55	2	10	20	15
						Overall:	16

<u>Ring Groove Carbon, % Filling</u>							
Fire Ring	15	5	20	10	5	10	11
No. 1	60	70	80	85	90	80	78
No. 2	5	5	10	5	5	15	8
No. 3	0	0	5	0	0	0	1
						Overall:	25

Piston Skirt Deposit Rating**
(Demerit)

Thrust	6.5 LS*	6.7 LSC	6.7 LSC	6.5 MSC	6.2 SC,PM	6.5 SC,PM	6.5 -
Anti-Thrust	6.0 LS	6.0 LS	6.0 LSC	6.0 LS	6.2 LS,SC	6.2 S,PM	6.1 -
						Overall:	6.5

*L = light, S = scratches, SC = scuffing, M = medium, PM = plating melted.
**0 = least, 9 most.

6V-537
TEST 8
Lubricant: AL-7172-L

POST TEST ENGINE CONDITION AND DEPOSITS

B. Pistons (continued)

	Cylinder Number						Average
	1L	2L	3L	1R	2R	3R	
Oil Control Ring Grooves (Demerit)							
Upper	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lower	4.0	4.0	4.0	4.0	4.0	4.0	4.0
						Overall:	4.0
Piston Groove Inside Diameter, % Ring Supporting Carbon							
No. 1	0	0	0	0	0	0	0
No. 2	20	34	29	30	55	66	42
						Overall:	21
Piston WTD* Rating	375	371	378	334	365	364	365
Ring Sticking							
No. 1	F	F	F	F	F	5%-P	
No. 2	F	F	F	F	F	F	
No. 3	F	F	F	F	F	F	
No. 4	F	F	F	F	F	F	
Piston Oil Drain Holes	----- 100% Open -----						

C. Exhaust Valves

Deposits

Head	----- AHC** -----
Face	----- all have carbon buildup causing leaking -----
Tulip	----- AHC to No. 9 ⁺ Lacquer -----
Stem	----- No. 9 Lacquer to Clean -----

Surface Condition

Freeness in Guide	----- Free -----
Head	----- Normal -----
Face	----- Leaking -----
Seat	----- Normal -----
Stem	----- Worn at Top -----
Tip	----- Tip -----

*CRC Weighted Total Deposits Rating (0 = least, 900 = most).

**HC = Hard Carbon; the number-letter prefix indicates carbon depth, with 1/4A = least through the alphabet to J = most.

⁺The higher the number, the darker the lacquer (0 = lightest, 9 = darkest).

6V-53T
TEST 8
Lubricant: AL-7172-L

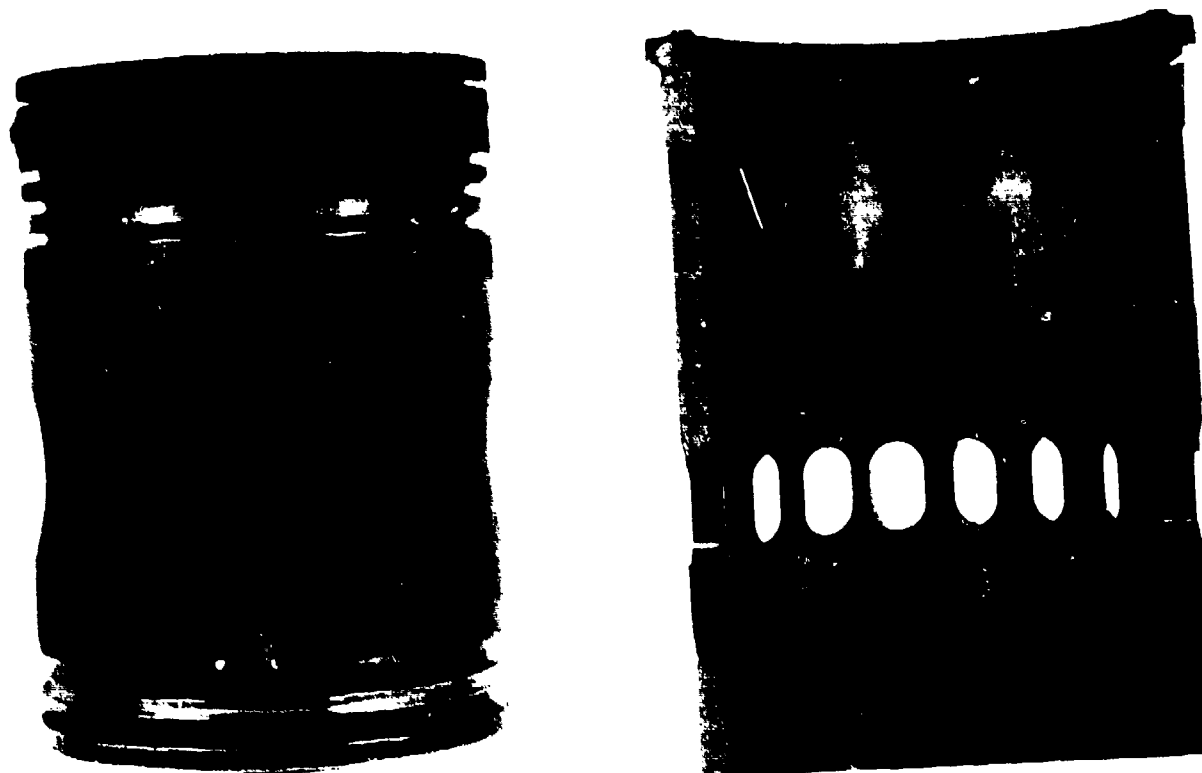
POST TEST ENGINE CONDITION AND DEPOSITS

D. Other Ratings

	<u>Cylinder Number</u>						<u>Average</u>
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	
<u>Tappets, Cams, and Rocker Arms</u>							
Tappet Deposit	-----	-----	-----	Clean	-----	-----	-----
Tappet Surface Condition	-----	-----	-----	Normal	-----	-----	-----
Cam Lobes	N *	N	SCR	N	N	N	N
<u>Rocker Arms</u>							
Tip	-----	-----	-----	Normal	-----	-----	-----
Bushing	-----	-----	-----	Normal	-----	-----	-----
Shaft	-----	-----	-----	Normal	-----	-----	-----
<u>Bearing Surface Condition</u>							
Main Bearings	-----	-----	-----	Not Removed	-----	-----	-----
Main Journals	-----	-----	-----	Not Removed	-----	-----	-----
Rod Bearings	-----	-----	-----	Normal	-----	-----	-----
Rod Journals	-----	-----	-----	Normal	-----	-----	-----
Piston Pin	N	LG	N	LG	MG	LG	LG
Pin Bushing	N	N	N	N	MG	N	N
<u>Combustion Chamber Deposits</u>	10% B 75% A 15% 1/2A	5% B 70% A 25% 1/2A	5% B 80% A 20% 1/2A	5% B 90% A 5% 1/2A	90% A 10% 1/2A	10% B 80% A 10% 1/2A	
Exhaust Port Deposits	-----	-----	-----	1/2 AHC	-----	-----	-----
Valve Covers, Cylinder Head Decks, and Oil Pan	-----	-----	-----	Clean	-----	-----	-----

* N = Normal, SCR = Scratched.

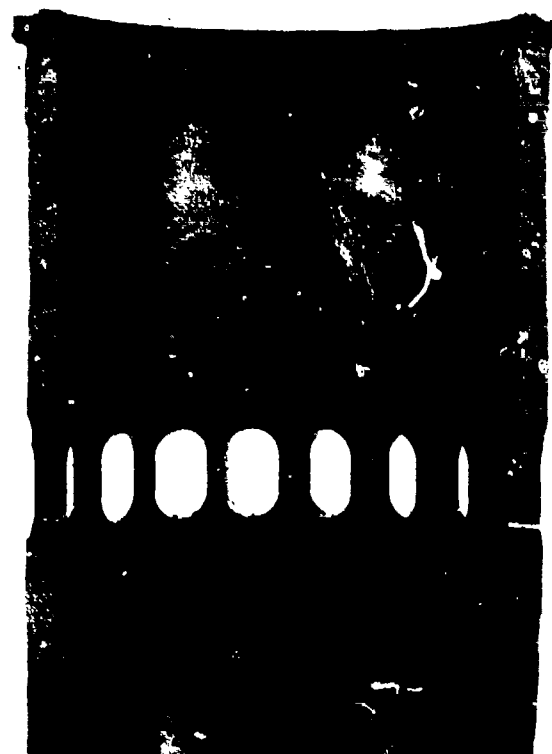
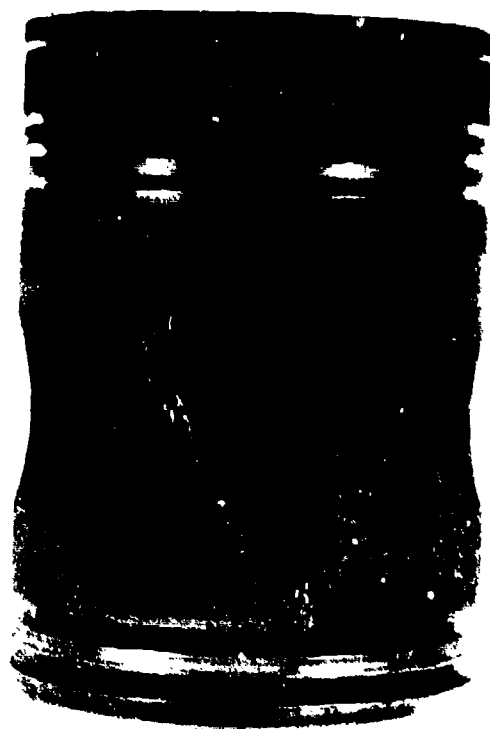
CONDITION OF PISTON AND CYLINDER
6V-53T TEST 8
Lubricant: AL-7172-L



1 - Left Thrust *

*Cylinder 1-Left had the most scuffing.

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 8
Lubricant: AL-7172-L



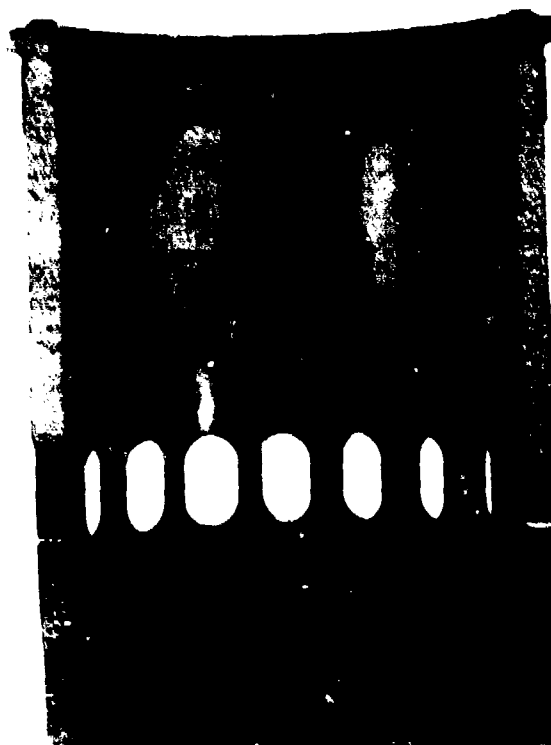
1 - Left Anti-Thrust*

*Cylinder 1-Left had the most scuffing.

CONDITION OF PISTON AND CYLINDER

6V-5VT TEST 8

Lubricant: AL-7172-L



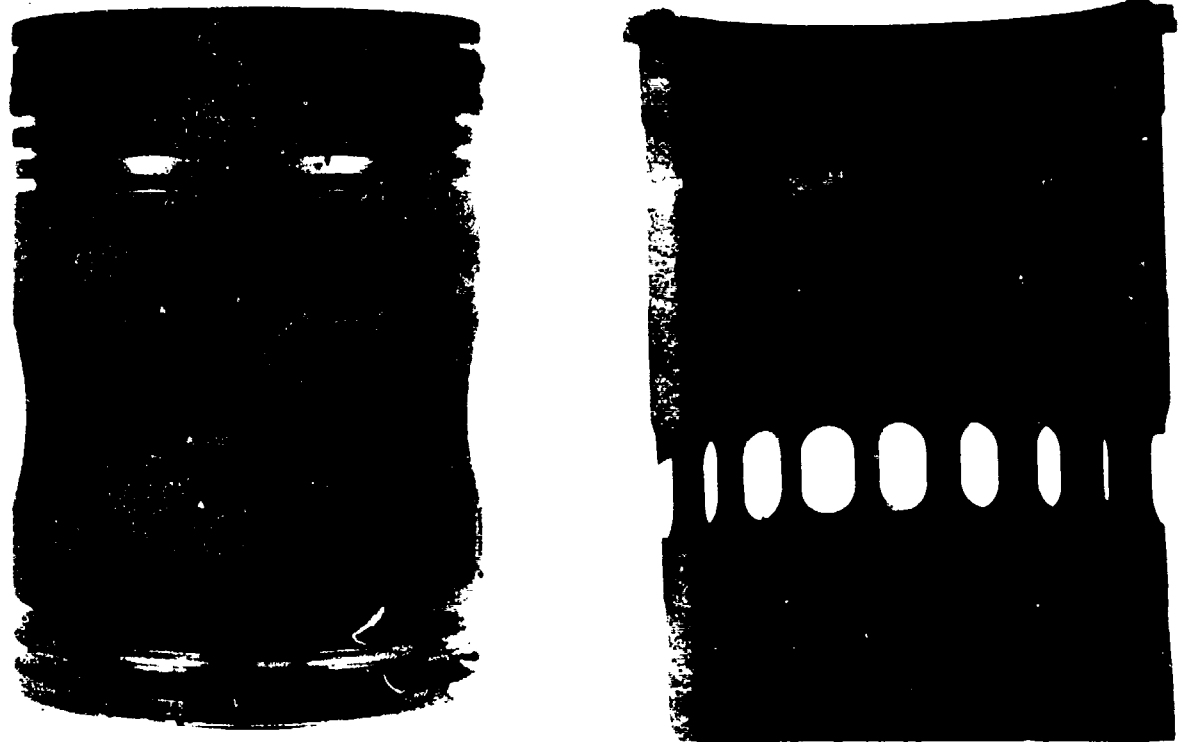
2 - Left Thrust^{*}

^{*} Cylinder 2 Left had the least scuffing.

CONDITION OF PISTON AND CYLINDER

6V-53T TEST 8

Lubricant: AL-7172-L



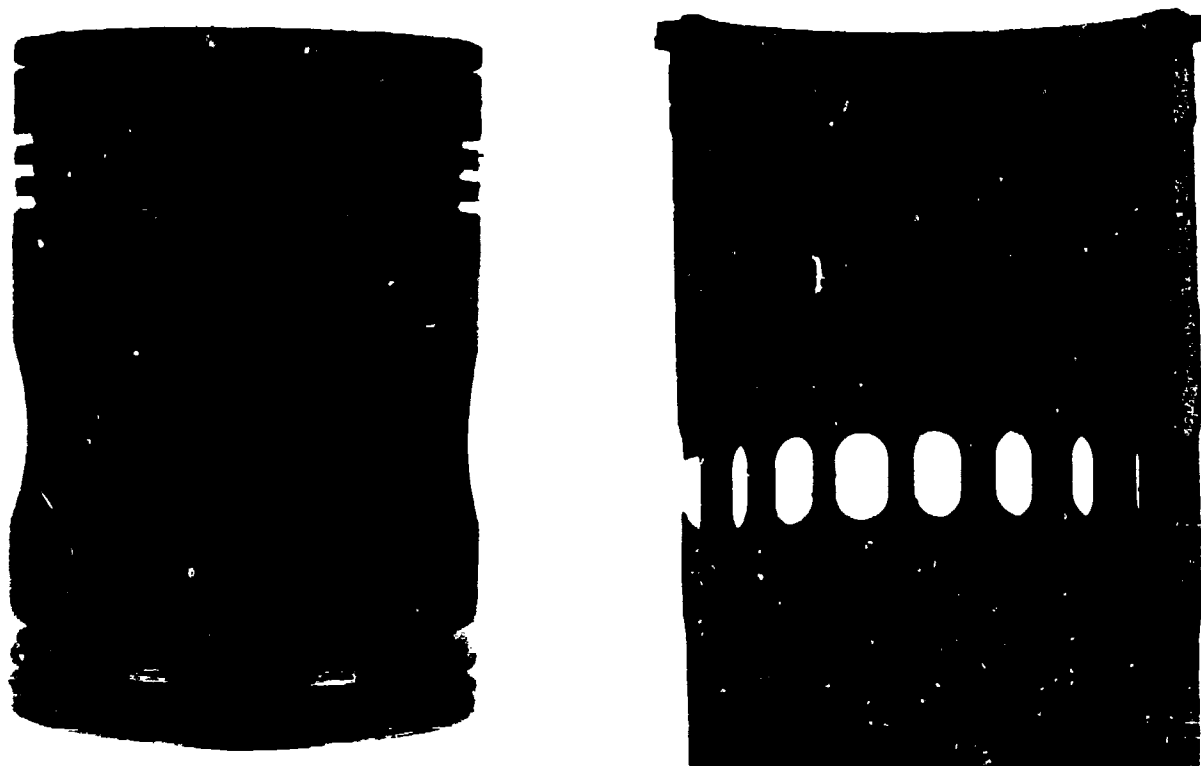
2 - Left Anti-Thrust *

*Cylinder 2-Left had the least scuffing.

CONDITION OF PISTON AND CYLINDER

6V-53T TEST 8

Lubricant: AL-7172-L



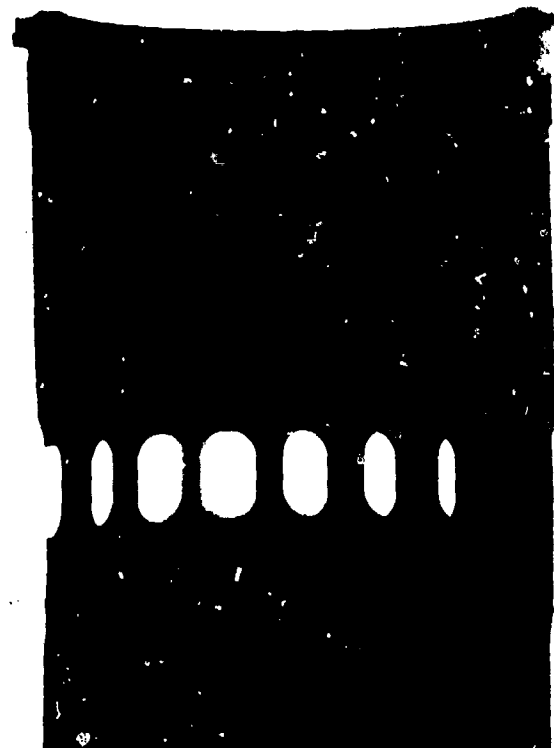
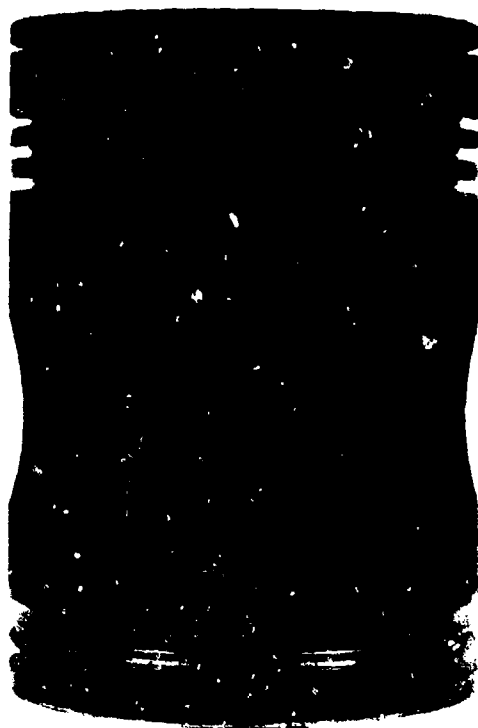
3 - Left Thrust *

*Piston 3-Left had the highest Weighted Total Deposits (WTD) rating.

CONDITION OF PISTON AND CYLINDER

6V-53T TEST 8

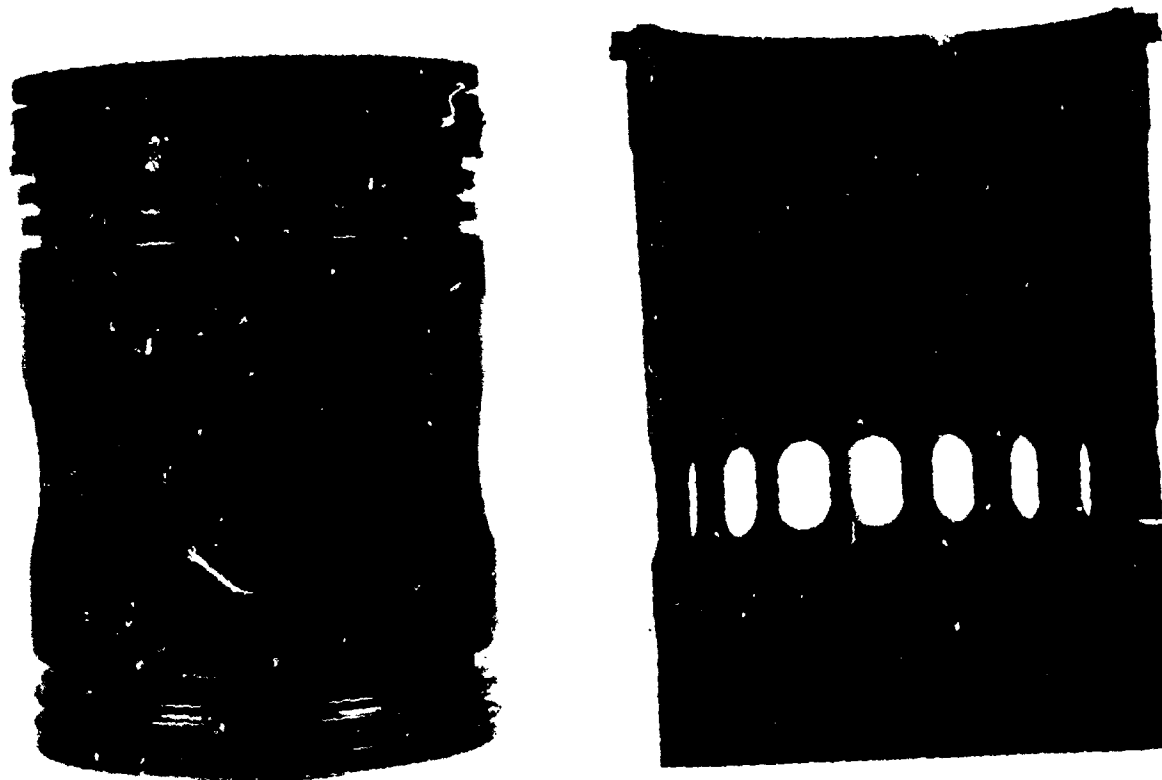
Lubricant: AL-7172-L



3 - Left Anti-Thrust*

*Piston 3-Left had the highest Weighted Total Deposits (WTD) rating.

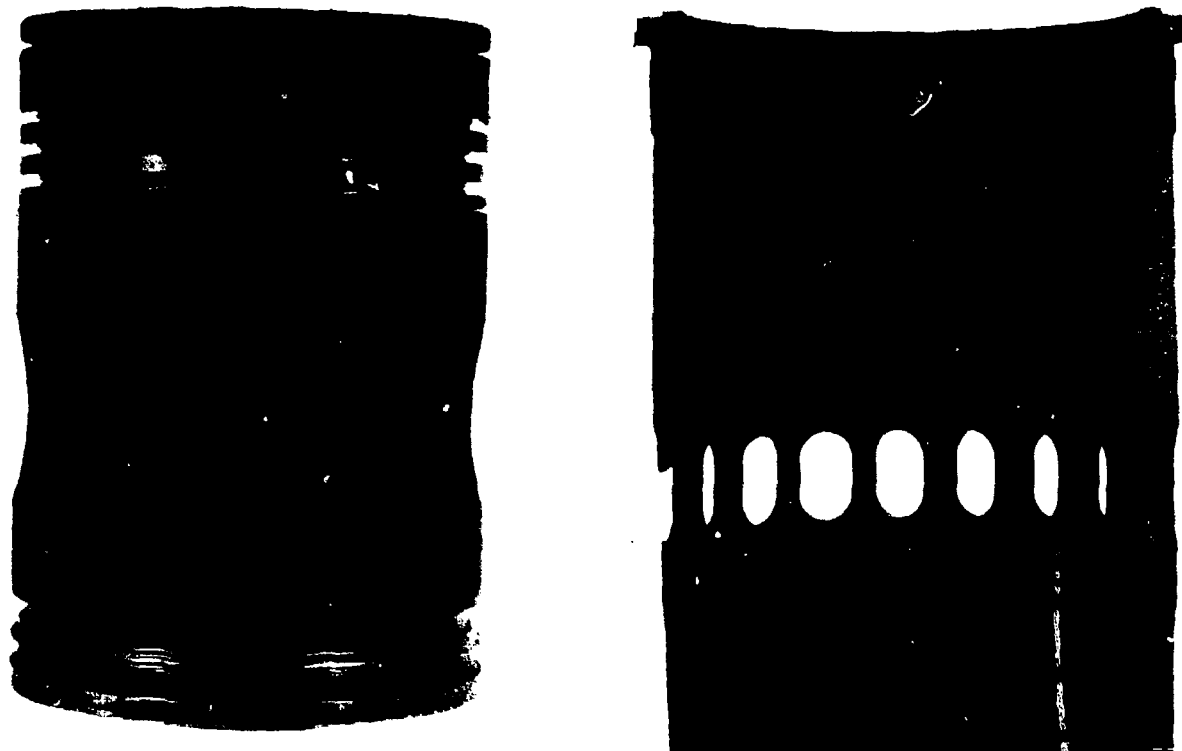
CONDITION OF PISTON AND CYLINDER
6V-53T TEST 8
Lubricant: AL-7172-L



1 - Right Thrust *

* Piston 1-Right had the lowest Weighted Total Deposits (WTD) rating.

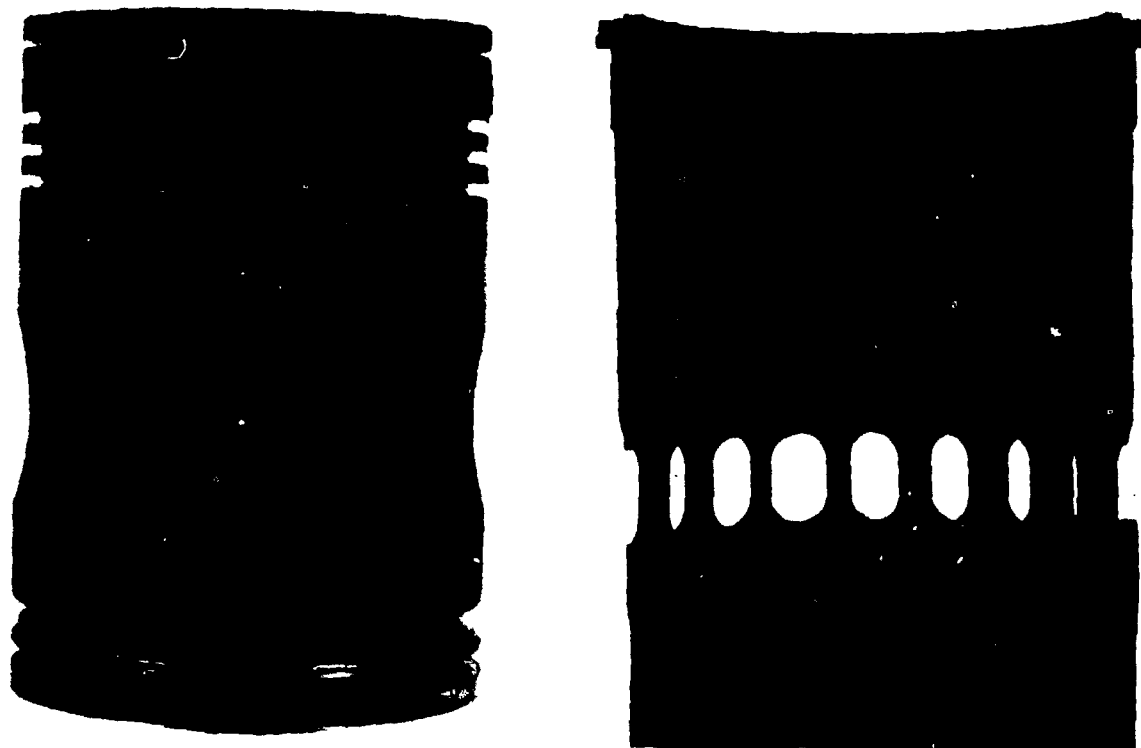
CONDITION OF PISTON AND CYLINDER
6V-53T TEST 8
Lubricant: AL-7172-L



1 - Right Anti-Thrust*

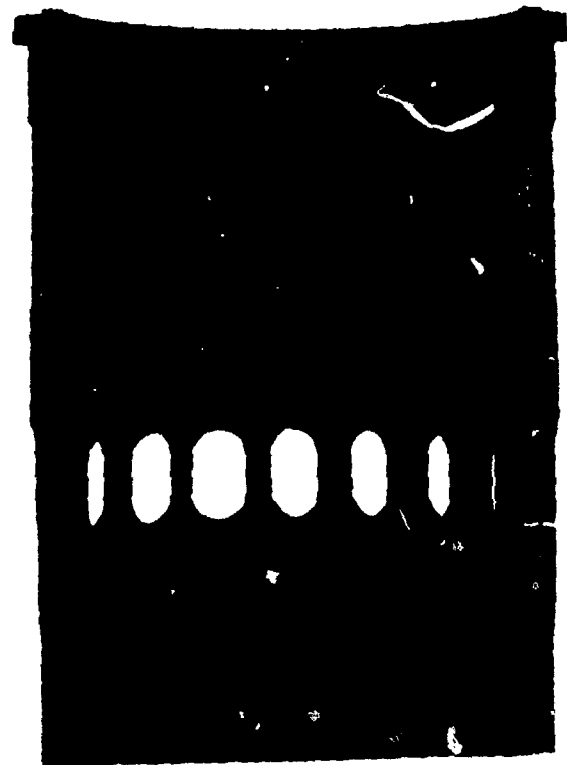
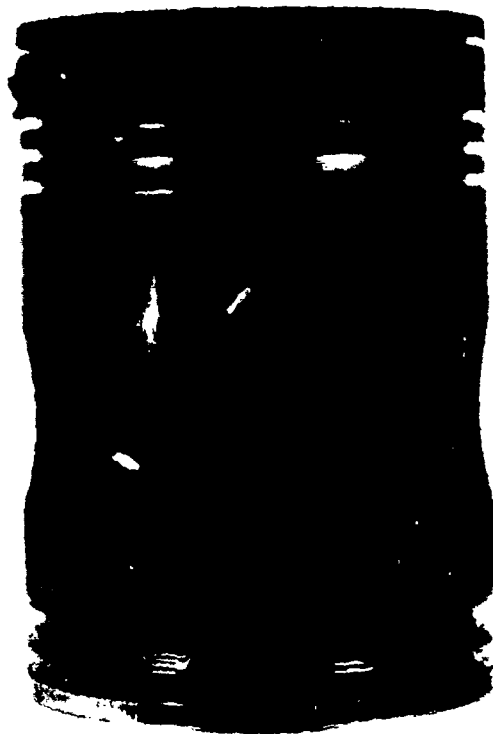
*Piston 1-Right had the lowest Weighted Total Deposits (WTD) rating.

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 8
Lubricant: AL-7172-L



2 - Right Thrust

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 8
Lubricant: AL-7172-L

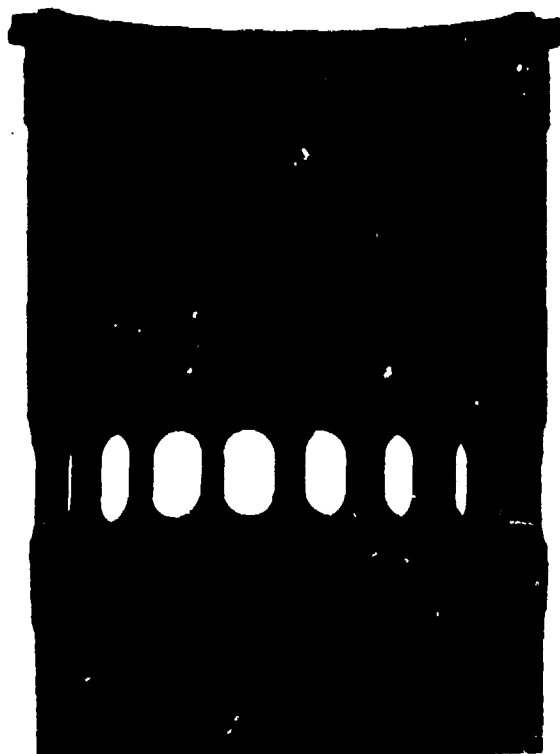
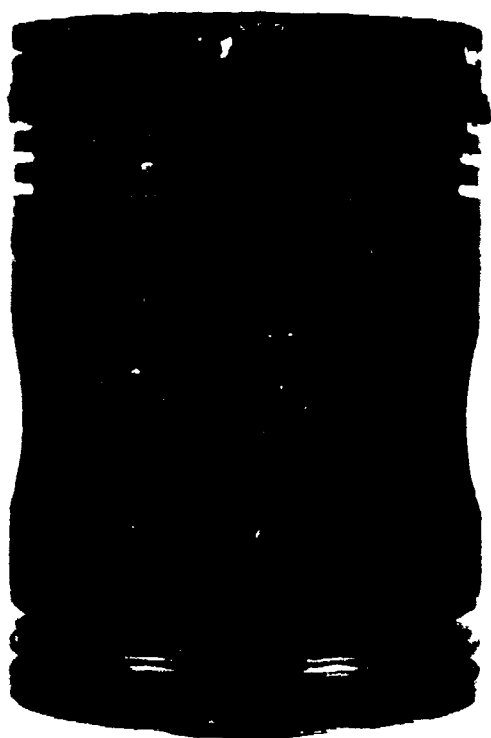


2 - Right Anti-Thrust

CONDITION OF PISTON AND CYLINDER

6V-53T TEST 8

Lubricant: AL-7172-L

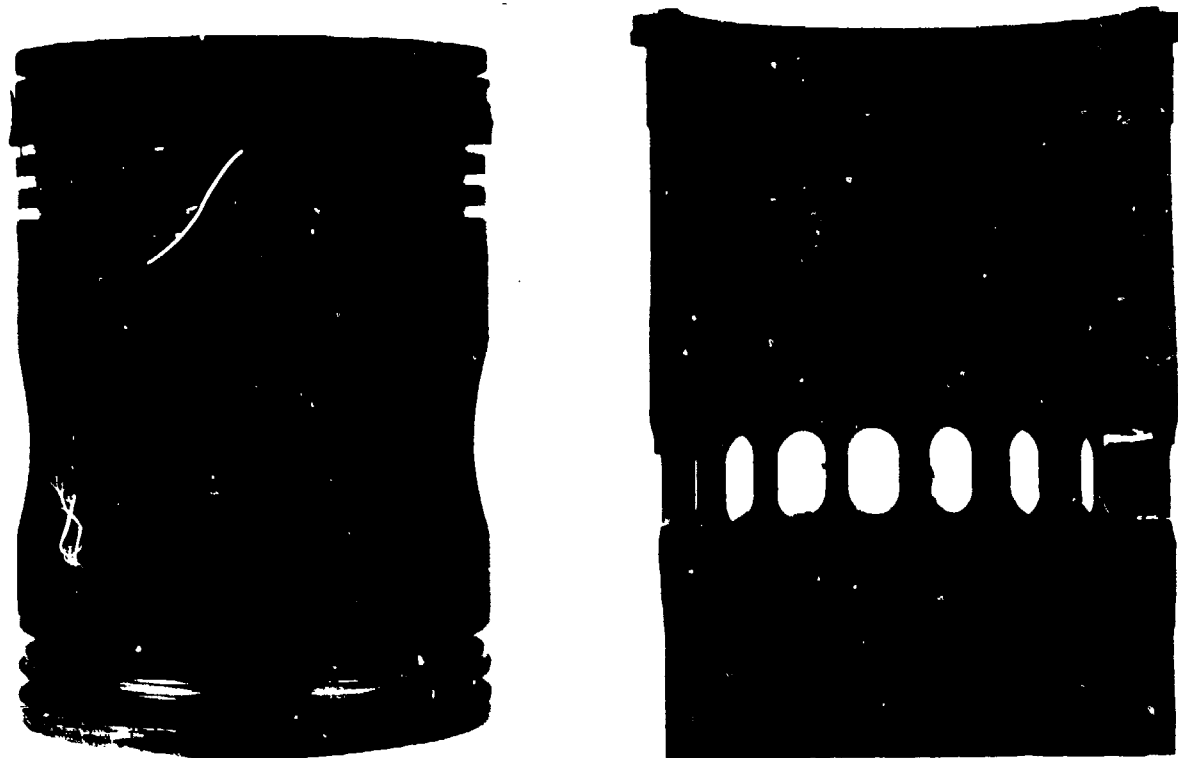


3 - Right Thrust

CONDITION OF PISTON AND CYLINDER

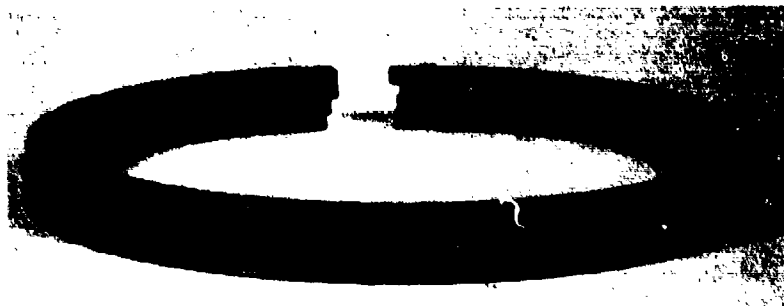
6V-53T TEST 8

Lubricant: AL-7172-L



3 - Right Anti-Thrust

CONDITION OF PISTON RINGS
6V-53T TEST 8
Lubricant: AL-7172-L



1 - Left

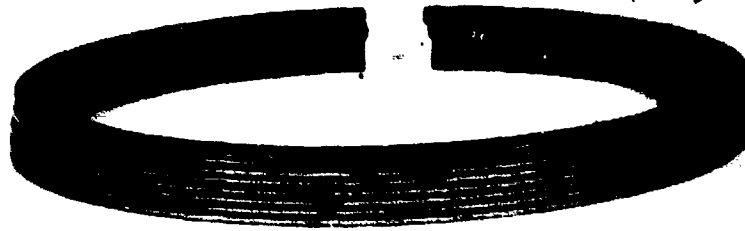


2 - Left

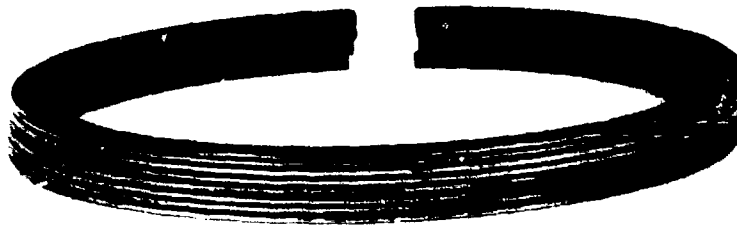


3 - Left

CONDITION OF PISTON RINGS
6V-53T TEST 8
Lubricant: AL-7172-L



1 - Right



2 - Right



3 - Right

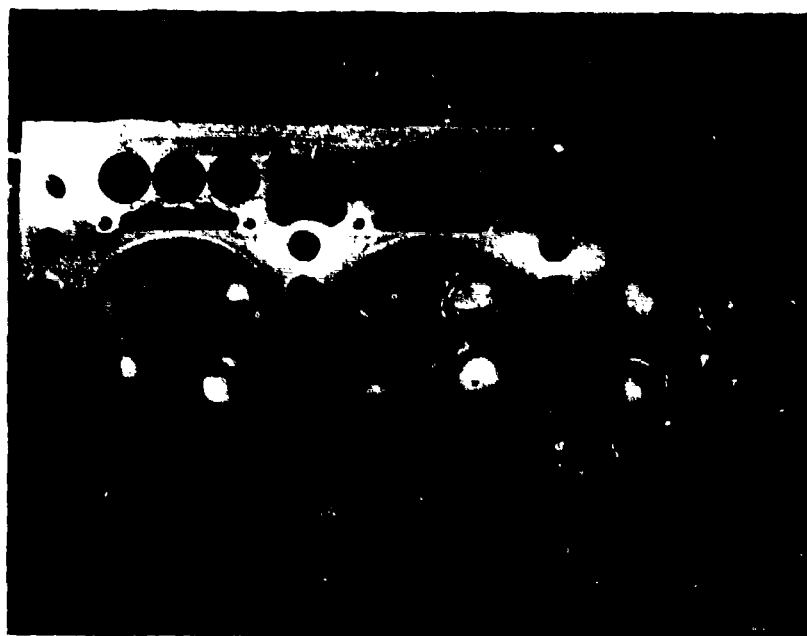
CONDITION OF CYLINDER HEADS
6V-53T TEST 8
Lubricant: AL-7172-I.



3 - Left

2 - Left

1 - Left



1 - Right

2 - Right

3 - Right

APPENDIX G

ENGINE-LUBRICANT COMPATIBILITY TEST #9

240-HOUR TRACKED-VEHICLE CYCLE

USING 6V-53T DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

Test Lubricant: AL-9249-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 9
Date Completed: 10 June 1980

Conducted by

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Ft. Belvoir, Virginia

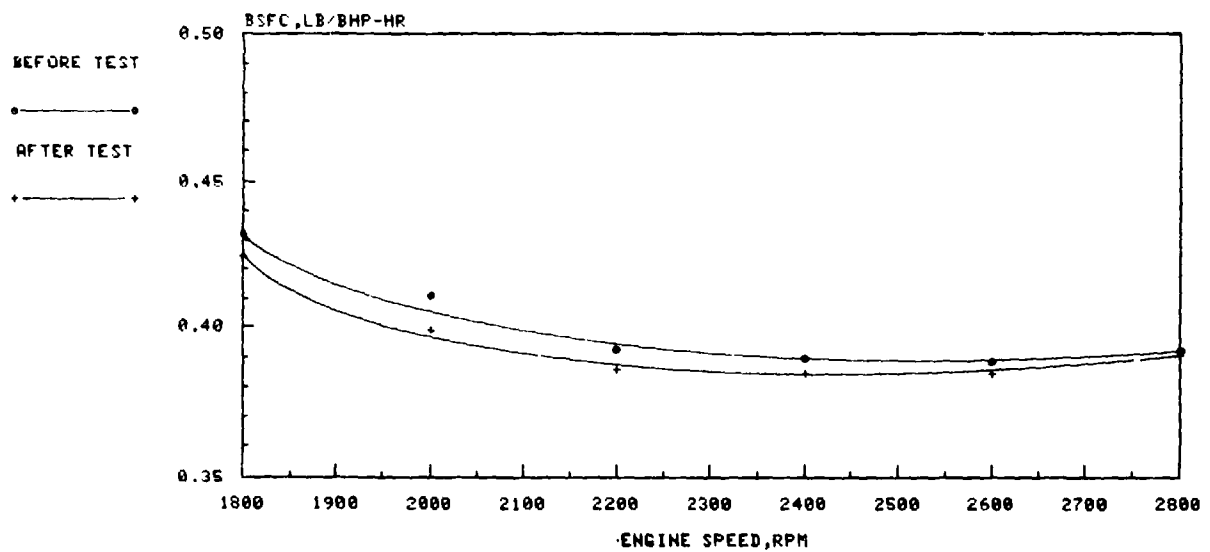
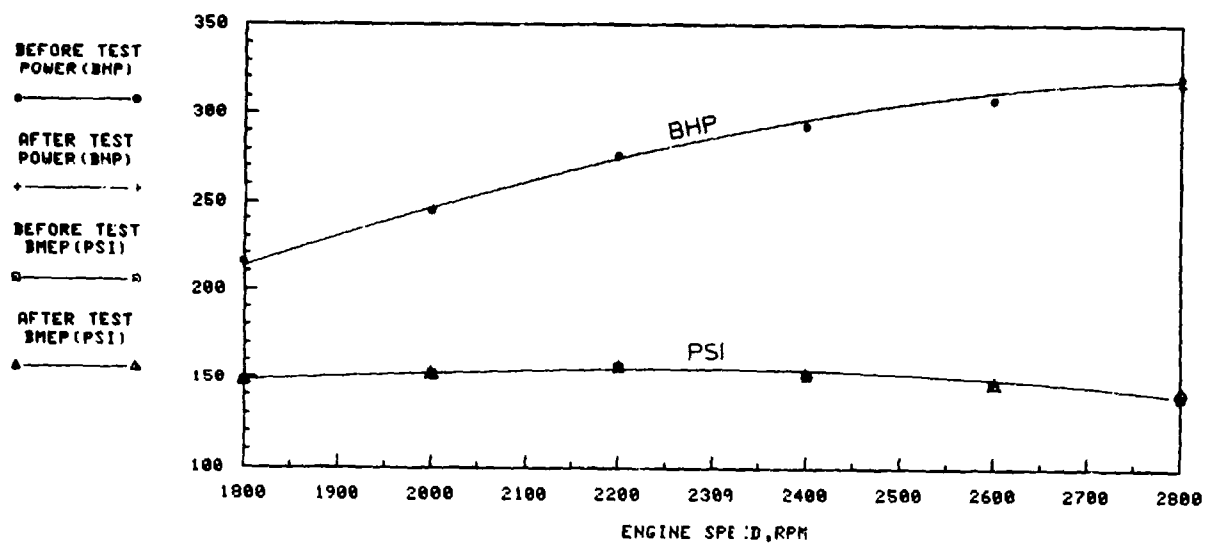
by

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V-53T
TEST 9
ENGINE REBUILD MEASUREMENTS
Model Number: 5063-5397
Serial Number: 6D-178671

	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Specified Limits</u>
<u>Cylinder Block Bore</u>				
Inside Diameter (bottom)	4.3570	4.3577	4.3572	4.3595 max
Out-of-Round	0.0000	0.0009	0.0003	0.0015 max
Taper	0.0000	0.0003	0.0002	0.0015 max
<u>Cylinder Liners (installed)</u>				
Inside Diameter	3.8755	3.8767	3.8760	3.8752-3.8767
Out-of-Round	0.0000	0.0008	0.0003	0.0020 max
Taper	0.0004	0.0010	0.0007	0.0010 max
Piston Diameter (at skirt)	3.8673	3.8678	3.8675	3.8669-3.3691
Piston Skirt to Cylinder Liner Clearance	0.0079	0.0092	0.0086	0.0061-0.0098
<u>Compression Rings</u>				
Gap (Fire)	0.0300	0.0350	0.0340	0.0200-0.0360
Gap (Others)	0.0200	0.0390	0.0300	0.0200-0.0360
<u>Ring-to-Groove Clearance</u>				
Top (Fire)	0.0030	0.0030	0.0030	0.0030-0.0060
No. 1	0.0070	0.0070	0.0070	0.0070-0.0100
No. 2 and 3	0.0050	0.0070	0.0060	0.0050-0.0080
<u>Oil Control Rings</u>				
Gap	0.0170	0.0200	0.0180	0.0100-0.0250
Ring-to-Groove Clearance	0.0020	0.0030	0.0020	0.0015-0.0055
<u>Piston Pin</u>				
Pin-to- Piston Bushing Clearance	0.0029	0.0031	0.0031	0.0025-0.0034
Pin-to- Conn. Rod Bushing Clearance	0.0013	0.0014	0.0014	0.0010-0.0019
Connecting Rod Bearing-to-Journal Clearance	0.0019	0.0022	0.0021	0.0011-0.0041
Main Bearing-to-Journal Clearance	Bearings not rebuilt or measured this test			0.0010-0.0040
Camshaft Bearing-to-shaft Clearance	Bearings not rebuilt or measured this test			0.0045-0.0060

6V-53T 240 HOUR TRACKED VEHICLE CYCLE BEFORE AND AFTER TEST 9 PERFORMANCE DATA



6V-53T
240-HOUR TRACKED VEHICLE CYCLE ENDURANCE TEST
TEST 9
OPERATING CONDITIONS SUMMARY
Lubricant: AL-2949-L Fuel: Caterpillar 1-H

	Maximum Power Mode (2800 rpm)		Maximum Torque Mode (2200 rpm)	
	Mean	Standard Deviation*	Mean	Standard Deviation
Engine Speed, rpm	2802	2	2203	3
Torque, Ft-lb (N-m)	592(803)	3(4)	657(891)	3(4)
Fuel Consumption, lb/hr (kg/hr)	123.9(56.25)	0.7(0.32)	106.7(48.44)	0.5(0.23)
Observed Power, Bhp (kW)	316(236)	2(1)	276(206)	1(1)
BSFC, lb/Bhp-hr (g/kW-hr)	0.392(238)	0.001(1)	0.387(235)	0.001(1)
<u>Temperatures, °F (°C)</u>				
Exhaust before turbo	992(533)	16(9)	1027(289)	15(8)
Exhaust after turbo	832(444)	8(4)	859(459)	8(4)
Water Jacket Inlet	158(70)	4(2)	155(68)	1(1)
Water Jacket Outlet	172(78)	3(2)	170(77)	1(1)
Oil Sump	238(114)	3(2)	227(108)	1(1)
Fuel at Filter	92(33)	1(1)	89(32)	1(1)
Inlet Air (at compressor)	93(34)	5(3)	93(34)	5(3)
Airbox	292(144)	5(3)	239(115)	1(1)
<u>Pressures</u>				
Exhaust before turbo, psi (kPa)	15.1(104)	0.2(1)	10.1(70)	0.1(1)
Exhaust after turbo, in. Hg (kPa)	2.9(9.8)	0.1(0.3)	1.9(6.4)	0.1(0.3)
Compressor Discharge, psi (kPa)	14.8(102)	0.2(1)	11.1(76)	0.2(1)
Blower Discharge, psi (kPa)	20.0(138)	0.2(1)	12.2(84)	0.2(1)
Oil Gallery, psi (kPa)	47(324)	1(7)	43(296)	1(7)
Intake Vacuum, in. H ₂ O (kPa)	7.8(1.94)	0.1(0.02)	4.7(1.17)	0.1(0.02)
<u>Ambient Conditions (both modes of operation)</u>				
Dry Bulb Temperature, °F (°C)	82(28)	4(3)		
Wet Bulb Temperature, °F (°C)	79(26)	3(2)		
Barometric Pressure, in. Hg (kPa)	29.14(98.78)	0.20(0.68)		

* 68% of the values for a given variable occur within ± 1 standard deviation of the mean;
95% occur within ± 2 standard deviations.

6V-53T
TEST 9
LUBRICANT ANALYSIS

Lubricant: AL-9249-L

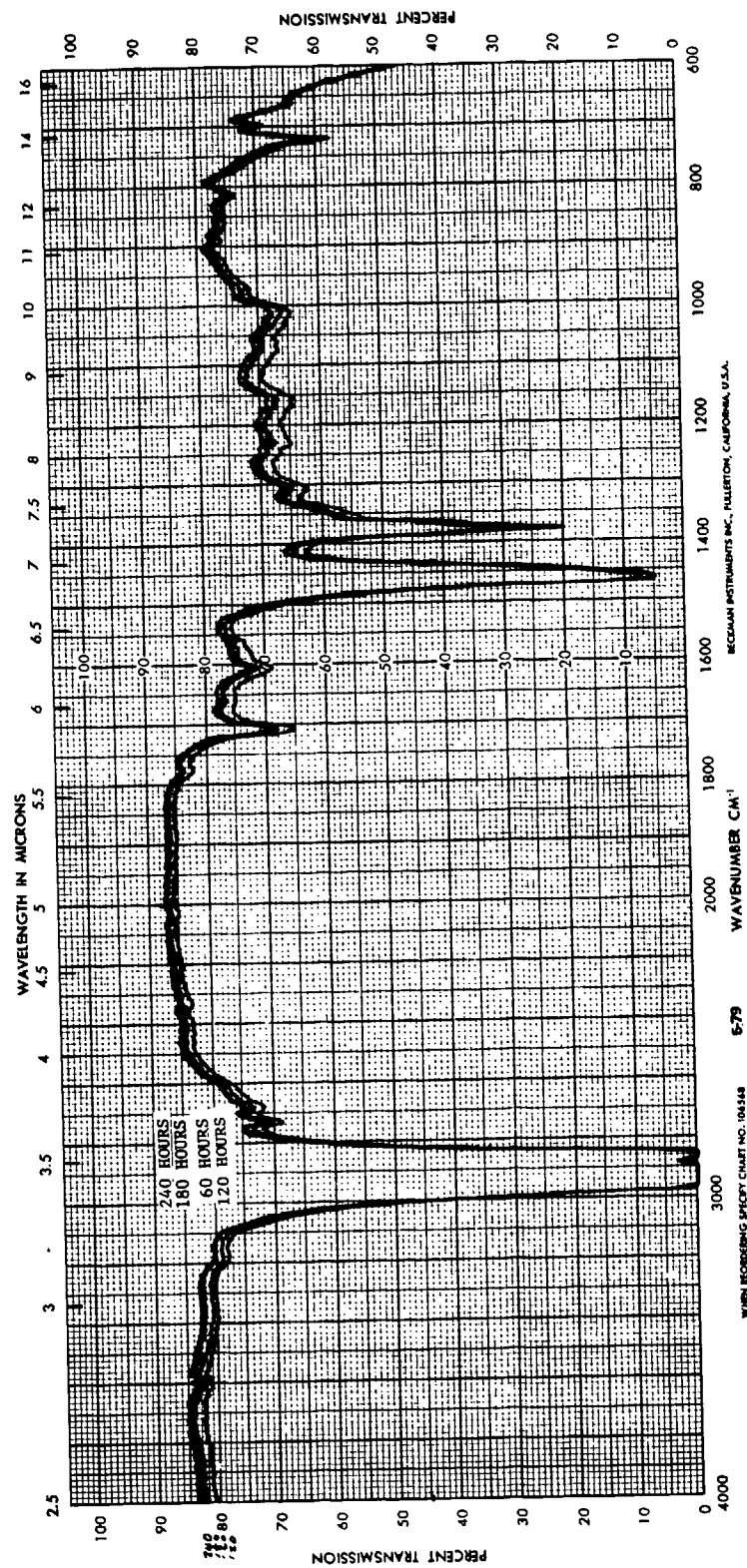
	ASTM Test Method	<u>Test time, Hours</u>				
		<u>0</u>	<u>60</u>	<u>120</u>	<u>180</u>	<u>240</u>
Apparent Viscosity at -29°C (-20°F), cP	D 2602	23000	43000	52000	30500	43000
Apparent Viscosity at -18°C (0°F), cP	D 2602	3900	6800	8700	6600	7800
Kinematic Viscosity at 40°C (104°F), cSt	D 445	96.7	120.0	127.5	118.3	122.1
Kinematic Viscosity at 100°C (212°F), cSt	D 445	13.9	15.5	16.2	15.6	15.5
Viscosity Index	D 2270	146	136	135	138	138
Total Acid Number, mg KOH/g	D 664	3.3	3.5	3.9	3.7	3.8
Total Base Number, mg KOH/g	D 664	6.5	4.7	4.4	4.9	4.6
Pentane B Insolubles, wt%	D 893	0.0	0.04	0.08	0.06	0.08
Toluene B Insolubles, wt%	D 893	0.0	0.04	0.08	0.06	0.08
Flash Point, °C (°F)	D 92	209(408)	218(424)	218(424)	218(424)	220(428)
Density at 16°C (60°F), gm/ml	D 287	0.88	0.88	0.89	0.89	0.89
Carbon Residue, wt%	D 524	1.2	1.7	1.9	1.8	1.9
Sulfated Ash, wt%	D 874	1.0	1.1	1.0	1.0	1.3

INFRARED SPECTRUM

6V-53T

TEST 9

Lubricant: AL-9294-L



6V-53T
TEST 9
Lubricant: AL-9249-L

TOTAL CONSUMPTION AND WEAR METALS BY XRF

<u>Test Time, Hours</u>	<u>Total Oil Consumed, lb (kg)</u>	<u>Wear Metals, ⁺ppm</u>	
		<u>Fe</u>	<u>Cu</u>
20	11.2(5.1)	37	ND*
30	19.4(8.8)	- ⁺⁺	-
40	22.6(10.3)	49	ND
50.5	33.1(15.0)	-	-
60	38.5(17.5)	57	ND
68	45.7(20.7)	-	-
80	52.7(23.9)	58	ND
93	59.5(27.0)	-	-
100	66.5(30.2)	55	ND
110	73.6(33.4)	-	-
120	86.0(39.0)	59	ND
130	93.4(42.3)	-	-
140	96.8(43.9)	28	ND
150	104.3(47.3)	-	-
160	110.1(49.9)	46	ND
170	117.6(53.3)	-	-
180	123.1(55.9)	54	ND
190	127.7(57.9)	-	-
200	136.3(61.8)	54	ND
213	143.7(65.2)	-	-
220	150.1(68.1)	71	10
233	157.1(71.2)	-	-
240	170.8(77.5)	59	ND

Average Oil Consumption Rate: 0.71 lb/hr (0.32 kg/hr)

⁺No other wear metals detected.

⁺⁺Oil samples for wear metal analysis not taken at these times.

*Not detected.

6V-53T
TEST 9
Lubricant: AL-9249-L

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change *

	Cylinder Number					
	1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0001	-0.0002	+0.0004	-0.0002	+0.0004	-0.0007
Middle	+0.0006	-0.0001	+0.0004	+0.0003	+0.0007	+0.0008
Bottom	+0.0001	+0.0004	+0.0004	+0.0002	-0.0001	+0.0006

	Cylinder Number					
	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0002	+0.0002	+0.0003	-0.0003	+0.0006	-0.0001
Middle	+0.0007	-0.0001	+0.0007	+0.0006	+0.0006	+0.0002
Bottom	+0.0003	+0.0004	+0.0003	-0.0001	+0.0003	+0.0005

	Average Change	
	T-AT	F-B
Top	+0.0003	-0.0005
Middle	+0.0006	+0.0003
Bottom	+0.0002	+0.0003

Overall Average Change: +0.0002 inch

Ring Number	Piston Ring End Gap Change						Average Change
	1L	2L	3L	1R	2R	3R	
1	+0.004	+0.001	+0.002	+0.004	+0.002	-0.003	+0.002
2	0.000	+0.001	+0.002	+0.005	+0.003	+0.001	+0.002
3	0.000	+0.001	+0.001	+0.003	+0.002	+0.001	+0.001
4	0.002	+0.003	+0.001	+0.003	0.000	+0.003	+0.002
5	+0.009	+0.008	+0.010	+0.010	+0.009	Broke	+0.009
6	+0.005	+0.008	+0.004	+0.008	+0.005	+0.004	+0.006
7	+0.008	+0.004	+0.008	+0.005	+0.006	+0.006	+0.006

Overall Average Change: +0.004 in.

*All dimensions given are in inches.

**T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction.

6V-53T
TEST 9
Lubricant: AL-9249-L

POST TEST ENGINE CONDITION AND DEPOSITS

A. Cylinder Liner

	<u>Cylinder Number</u>						<u>Average</u>
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	
Intake Port Plugging, % restriction	<1	<1	<1	<1	<1	<1	<1
<u>Liner Scuffing, % Area</u>							
Thrust	5	5	5	10	60	5	15
Anti-Thrust	2	2	5	10	20	5	7
Total	4	4	5	10	40	5	11
						Overall:	11
Liner Glazed, % Area	15	10	15	20	10	10	13
Liner Lacquer, % Area	85	90	85	80	90	90	87

B. Pistons

<u>Ring Face Burn, % Area</u>							
Fire Ring	1	3	1	5	20	1	5
No. 1	0	2	1	45	75	55	30
No. 2	0	0	0	60	90	25	29
No. 3	0	0	0	35	40	5	13
						Overall:	19
<u>Ring Groove Carbon, % Filling</u>							
Fire Ring	15	20	15	25	30	25	22
No. 1	70	75	85	90	85	95	83
No. 2	0	5	0	5	5	0	3
No. 3	0	0	0	0	0	0	0
						Overall:	27
<u>Piston Skirt Deposit Rating** (Demerit)</u>							
Thrust	5.0	5.5	5.0	5.2	5.5	5.5	5.3
	LS*	LS	LPM,LS	LSC,LS	L to MSC	N	
Anti-Thrust	5.0	5.2	5.5	5.0	5.0	5.5	5.2
	LS	LS	LS	LSC	LS	LS	
						Overall:	5.3

*L = Light, S = Scratches, PM = Plating Melted, N = Normal, SC = Scuffing
**0 = least, 9 = most

6V-53T
TEST 9
Lubricant: AL-9249-L

POST TEST ENGINE CONDITION AND DEPOSITS

B. Pistons (continued)

	Cylinder Number						<u>Average</u>
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	
<u>Oil Control Ring Grooves</u> <u>(Demerit)</u>							
Upper	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lower	4.0	4.0	4.0	4.0	4.0	4.0	4.0
						Overall:	4.0

Piston Groove Inside
Diameter, % Ring
Supporting Carbon

No. 1	0	0	0	0	0	0	0
No. 2	53	99	19	48	56	93	61
						Overall:	31

Piston WTD* Rating	319	369	351	352	353	350	349
--------------------	-----	-----	-----	-----	-----	-----	-----

Ring Sticking

No. 1	5%-p**	F	S	F	F	F
No. 2	F	F	S	F	F	F
No. 3	F	F	F	F	F	F
No. 4	F	F	F	F	F	F

Piston Oil Drain Holes <----- 100% OPEN ----->

C. Exhaust Valves

Deposits

Head	<----- AHC ⁺ to soot ----->
Face	<----- 1/4 AHC to No. 9 ⁺⁺ lacquer ----->
Tulip	<----- AHC to No. 9 lacquer ----->
Stem	<----- 1/4 AHC to clean ----->

Surface Condition

Freeness in Guide	F	F	F	F	F	F
Head	N	N	N	N	N	N
Face	<- light pitting with some leakage ->					
Seat	<----- light pitting ----->					
Stem	N	N	N	N	N	N
Tip	N	N	N	N	N	N

*CRC Weighted Total Deposits (0 = least, 900 = most)

**p = Pinched, F = Free, S = Stuck

⁺HC = Hard Carbon; the number-letter prefix indicates carbon depth with 1/4A = least to J = most.

⁺⁺ = The higher the number, the darker the lacquer. (0 - lightest, 9 = darkest

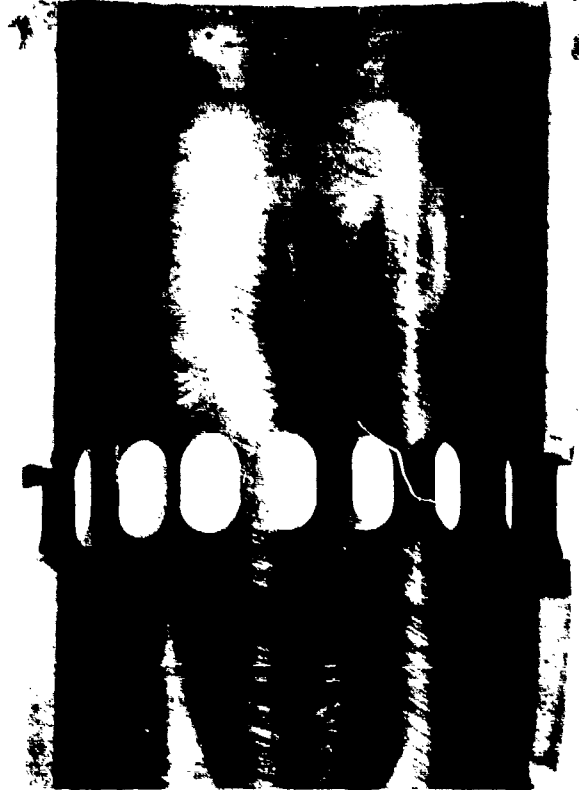
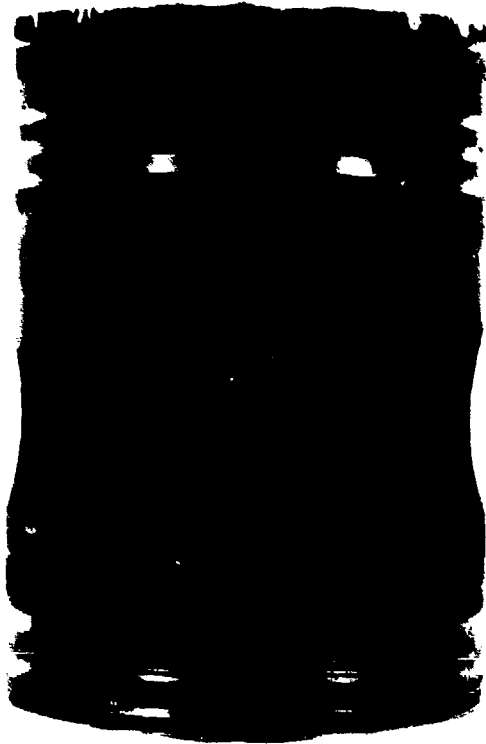
6V-53T
TEST 9
Lubricant: AL-9249-L

POST TEST ENGINE CONDITION AND DEPOSITS

C. Other Ratings

	<u>Cylinder Number</u>						<u>Average</u>
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	
<u>Tappets, Cams,</u>							
<u>Rocker Arms</u>							
Tappet Deposit	< _____ clean _____ >						
Tappet Surface	< _____ normal _____ >						
Condition	< _____ normal _____ >						
Cam Lobes	< _____ normal _____ >						
<u>Rocker Arms</u>							
Tip	< _____ normal _____ >						
Bushing	< _____ normal _____ >						
Shaft	< _____ normal _____ >						
<u>Bearing Surface</u>							
<u>Condition</u>							
Main Bearings	#1 and #2 main bearings and journals						
and Main	inspected and found to be in excellent						
Journals	condition						
Rod Bearings	< _____ normal _____ >						
Rod Journals	< _____ normal _____ >						
Piston Pin	lt. bluing < _____ normal _____ >						
Pin Rushing	< _____ some wear on all _____ >						
<u>Combustion Chamber</u>							
<u>Deposits</u>							
(AHC)	85%	80%	80%	90%	85%	80%	83%
(1/4 AHC)	15%	20%	20%	10%	15%	20%	17%
<u>Valve Covers, Cylinder Head</u>							
<u>Decks, and Oil Pan</u>	< _____ clean _____ >						

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



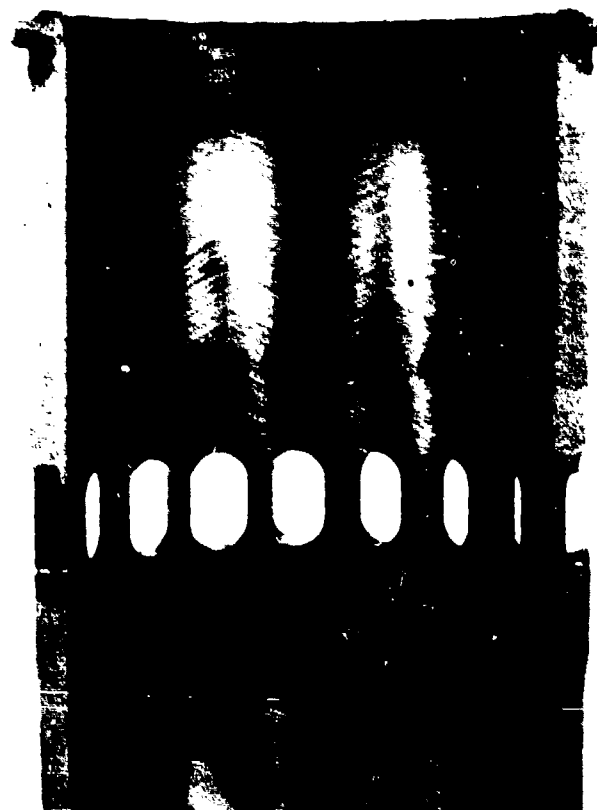
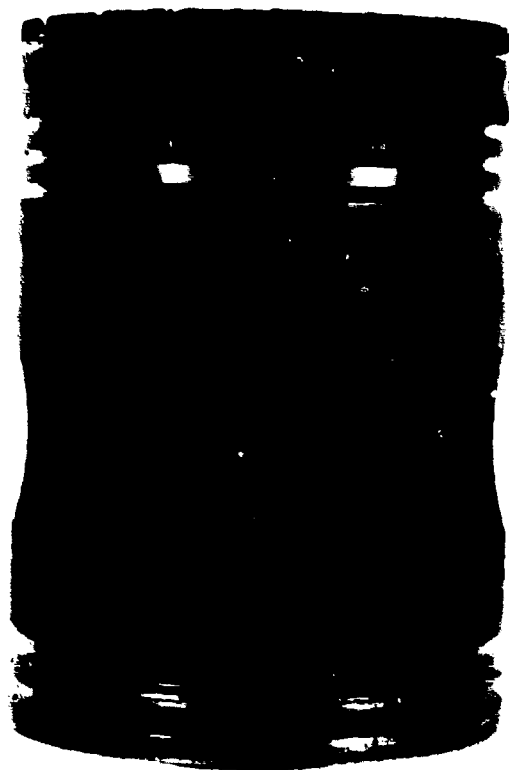
1-Left Thrust*

*Cylinders 1-Left and 2-Left had the least scuffing
Piston 1-Left had the lowest Weighted Total Deposits (WTD) rating

CONDITION OF PISTON AND CYLINDER

6V-53T TEST 9

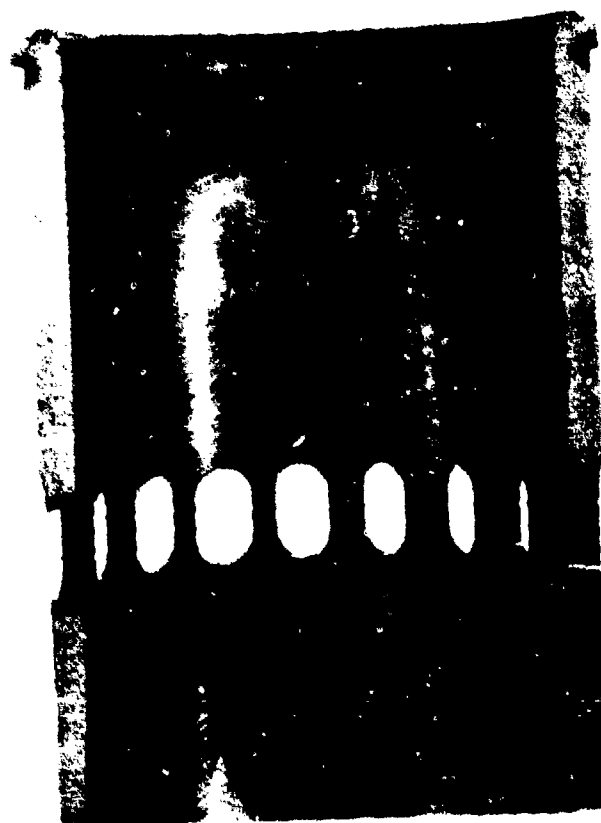
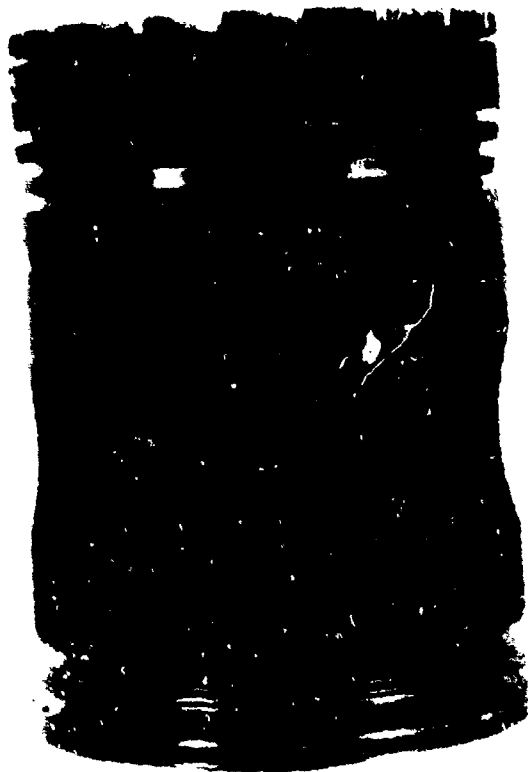
Lubricant: AL-9249-L



1-Left Anti-Thrust*

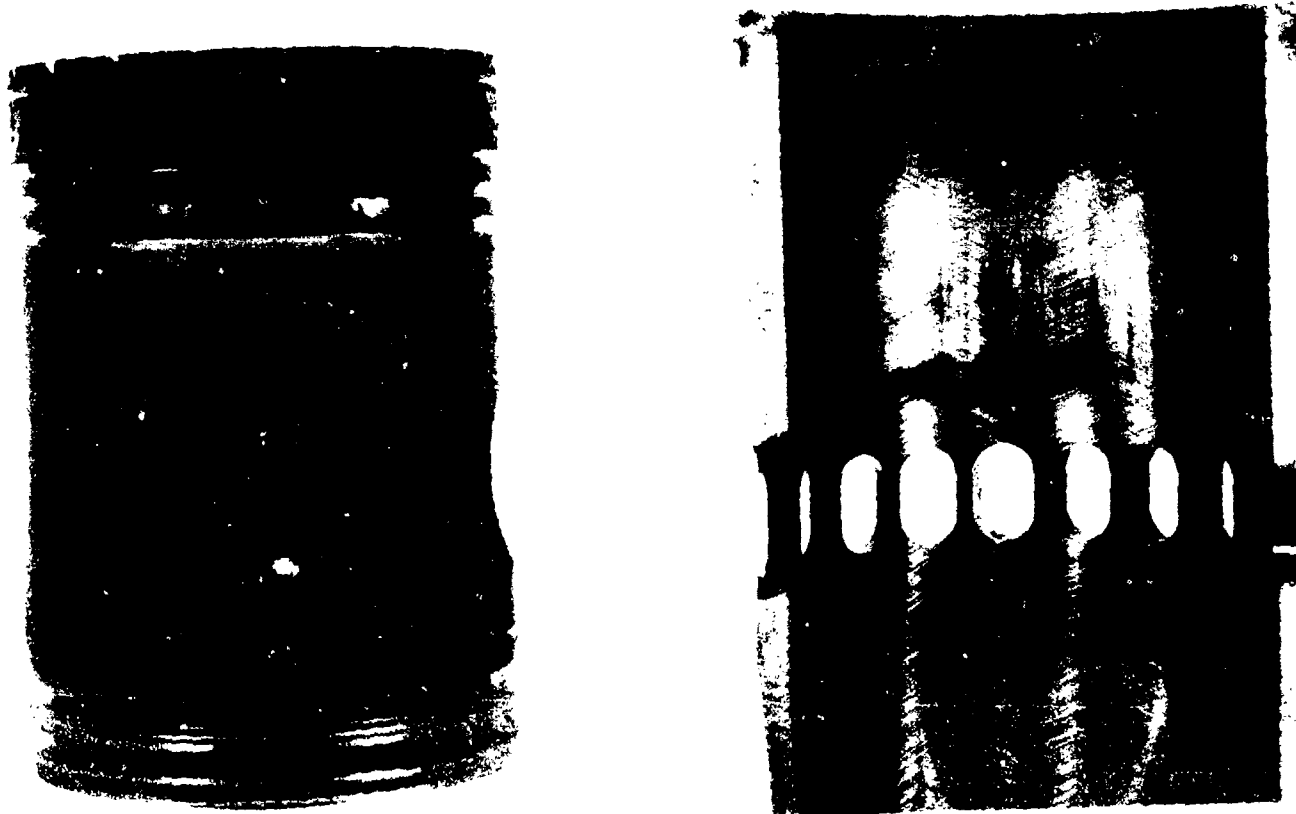
*Cylinders 1-Left and 2-Left had the least scuffing
Pistons 1-Left had the lowest Weighted Total Deposits (WTD) rating

CONDITIONS OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



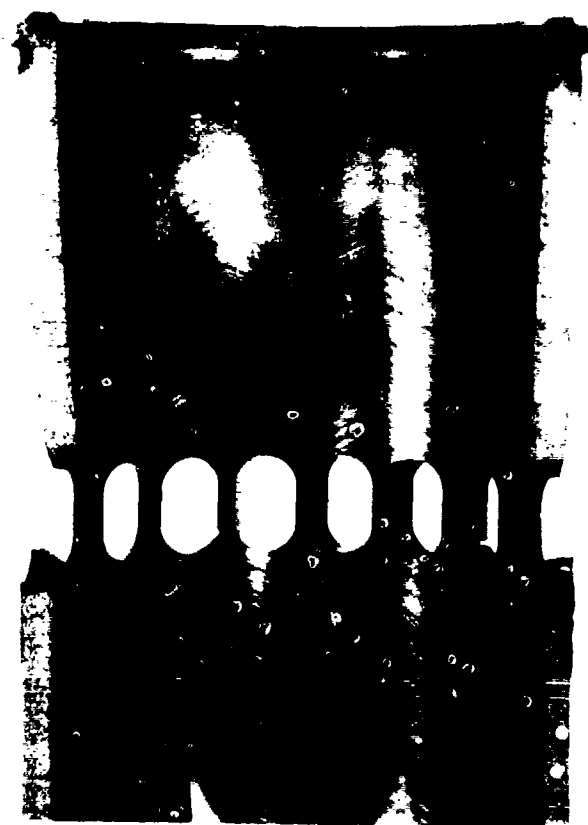
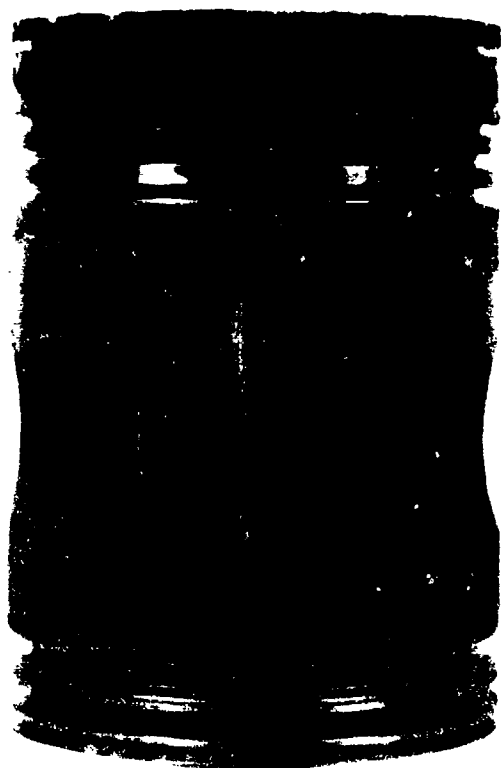
2-Left Thrust

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



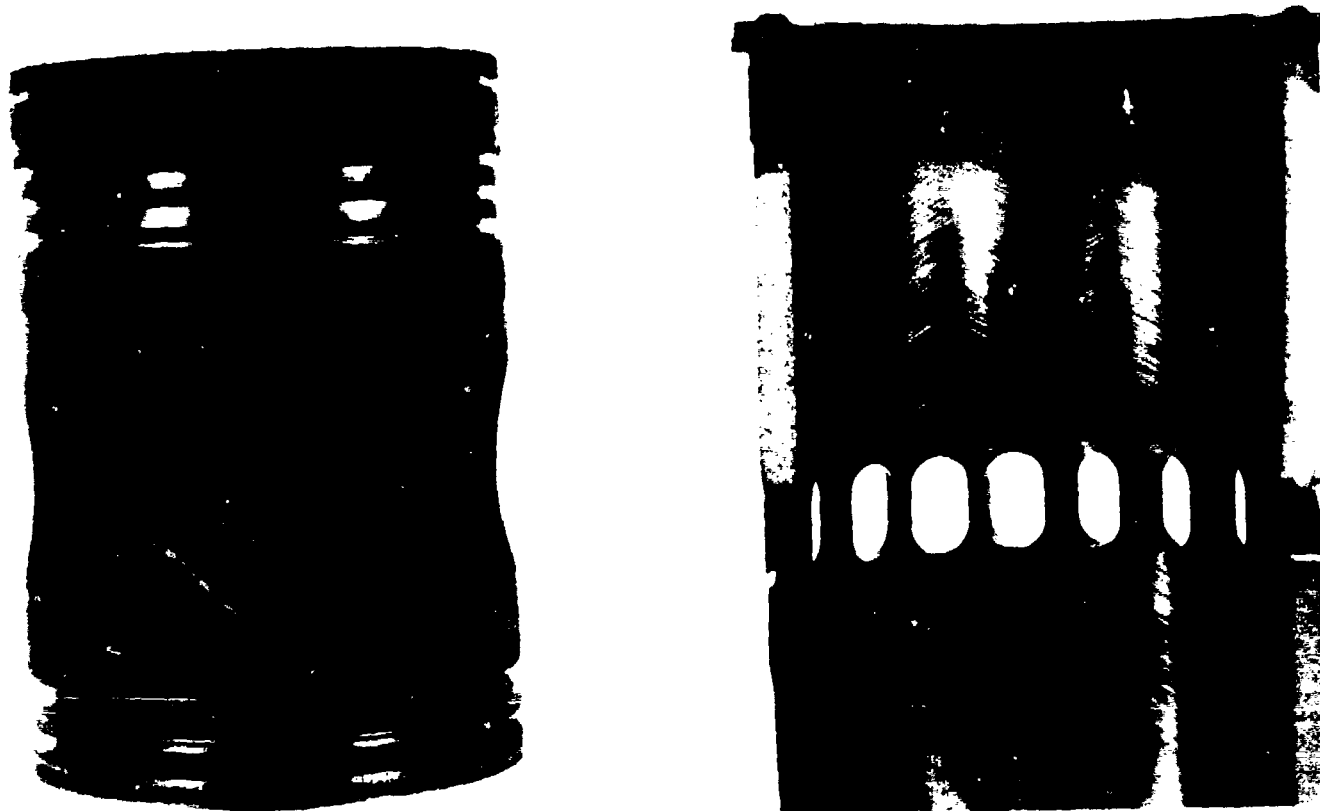
2-Left Anti-Thrust

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



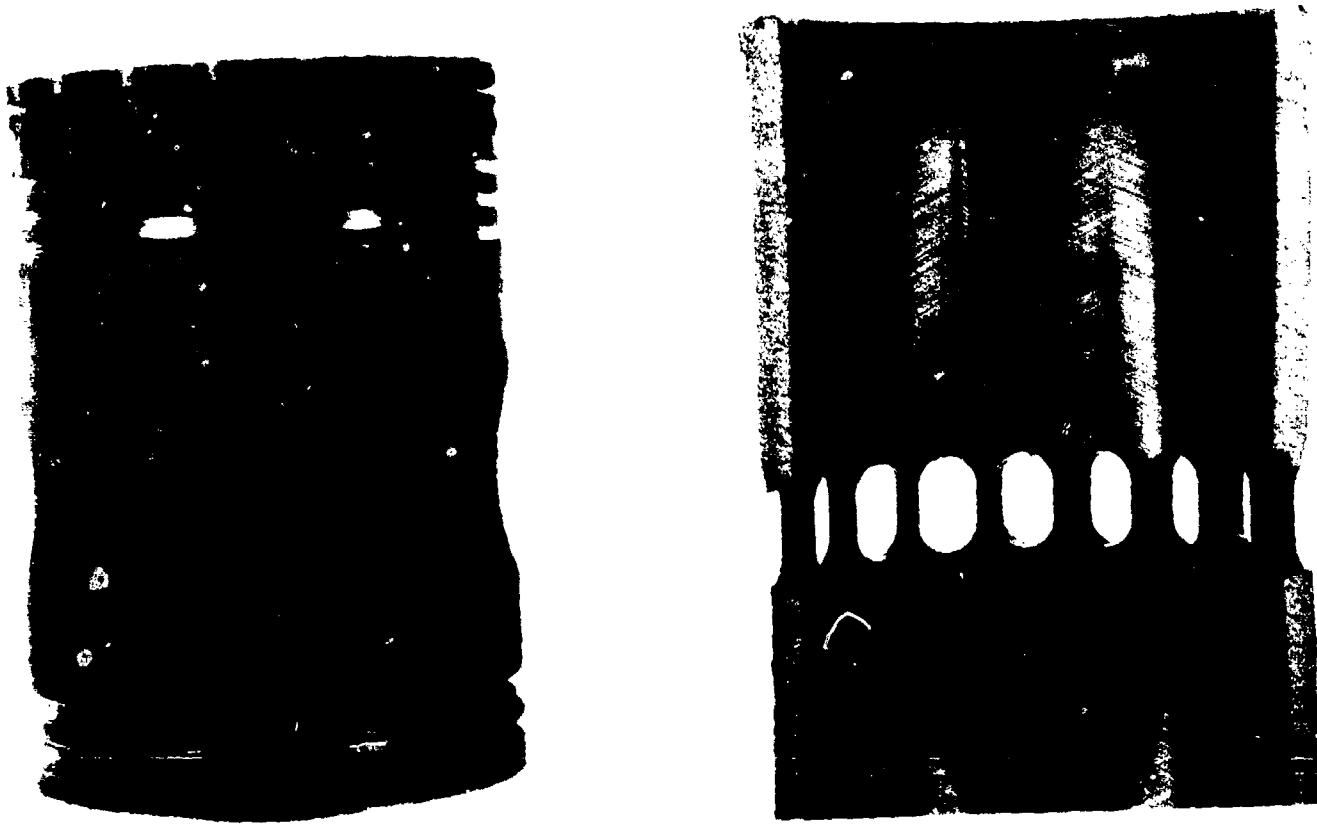
3-Left Thrust

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



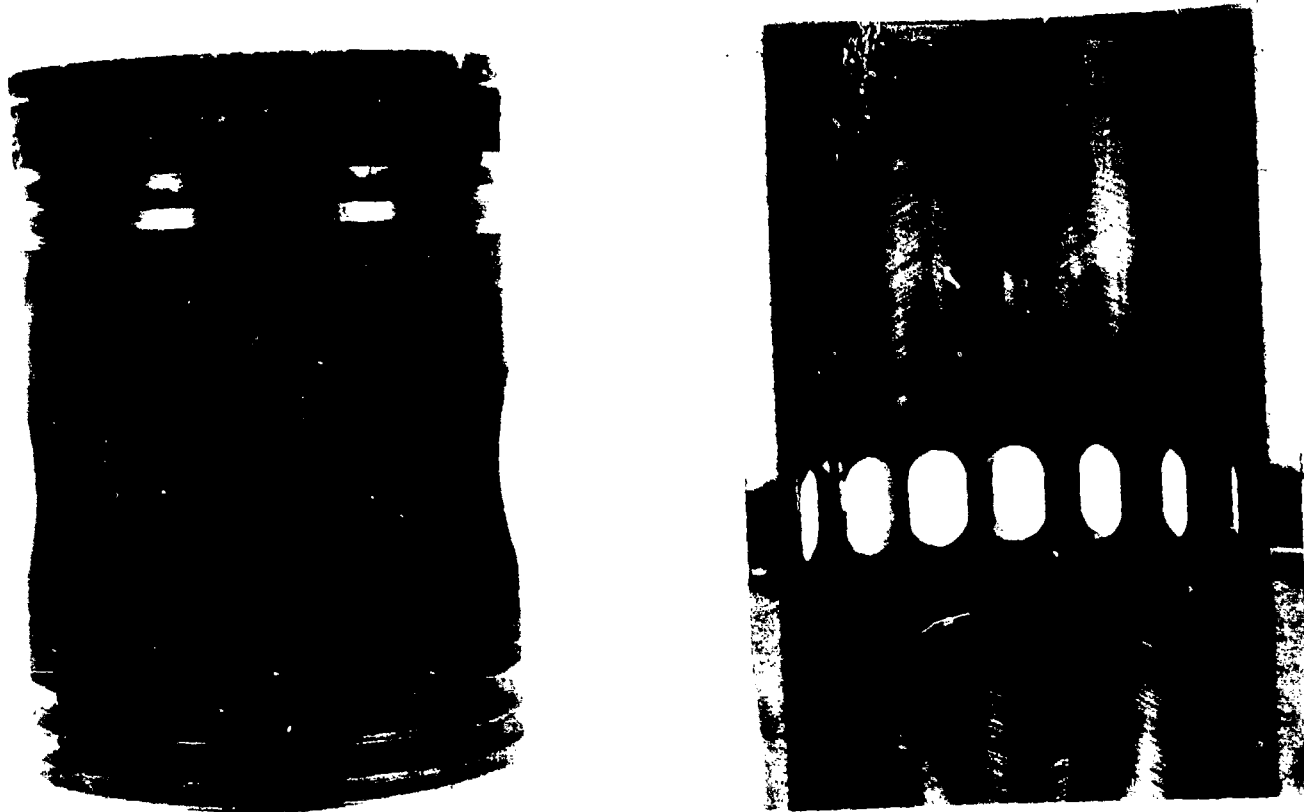
3-Left Anti-Thrust

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



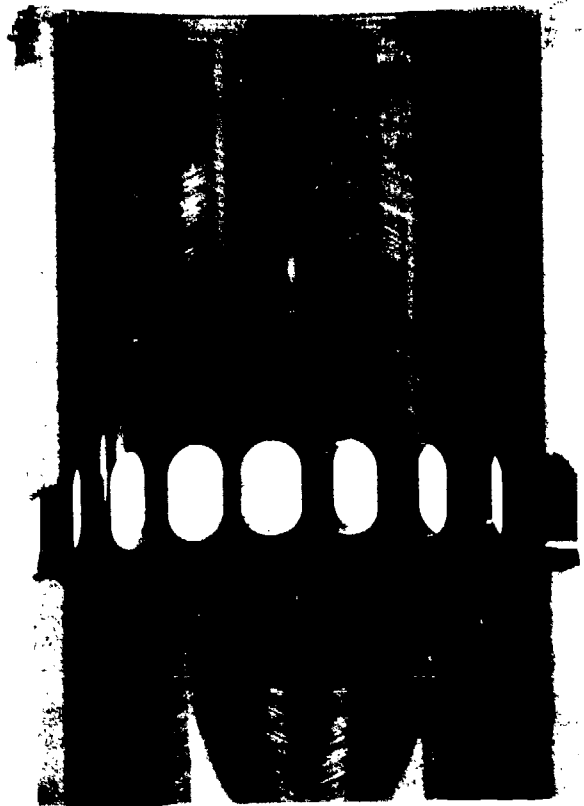
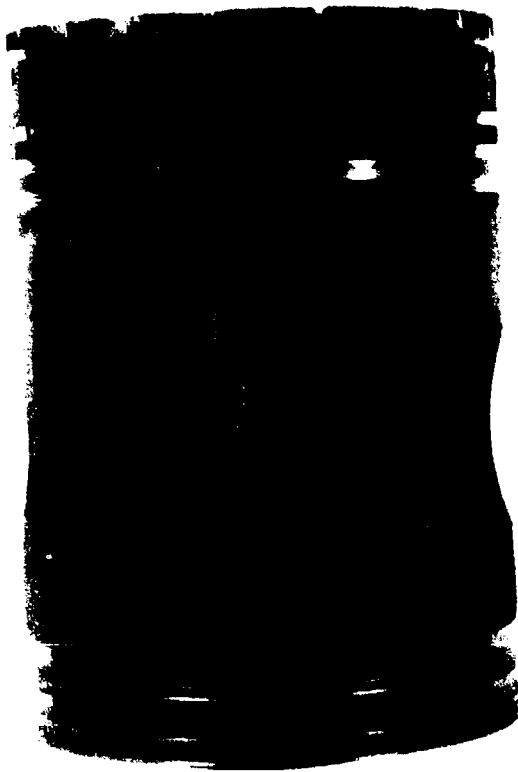
1-Right Thrust

CONDITION OF PISTON AND CYLINDER
6V-63T TEST 9
Lubricant: AL-9249-L



1-Right Anti-Thrust

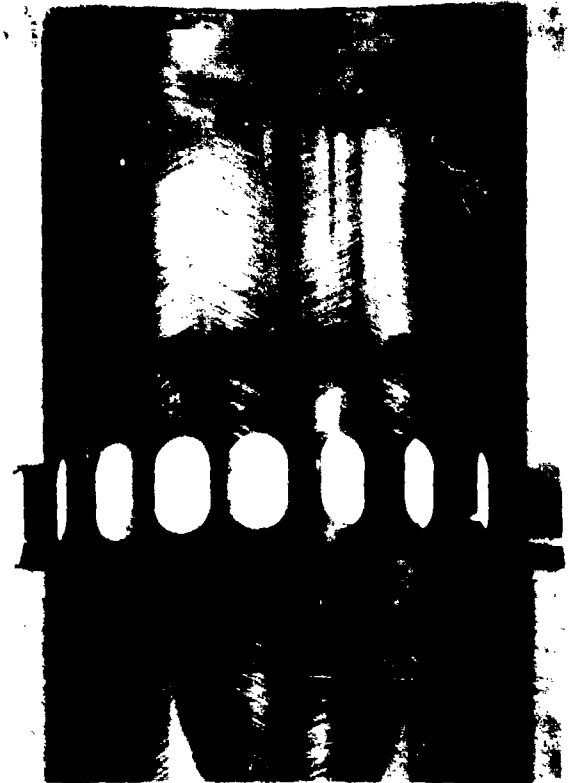
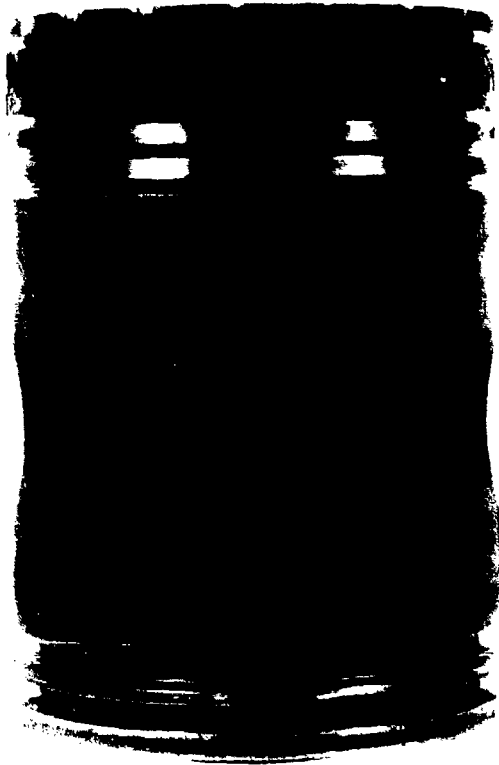
CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



2-Right Thrust*

*Cylinder 2-Right had the most scuffing
Piston 2-Right had the highest Weighted Total Deposits (WTD) rating

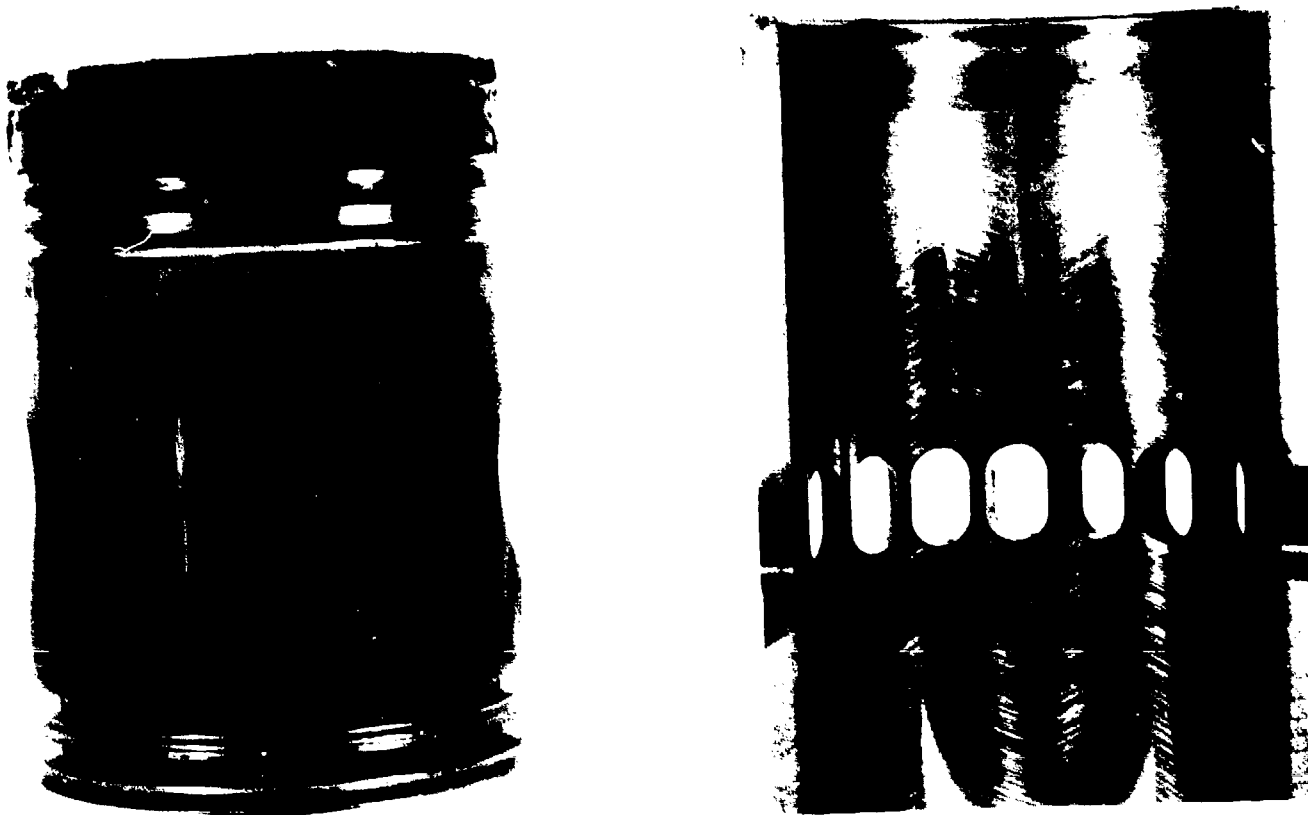
CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



2-Right Anti-Thrust*

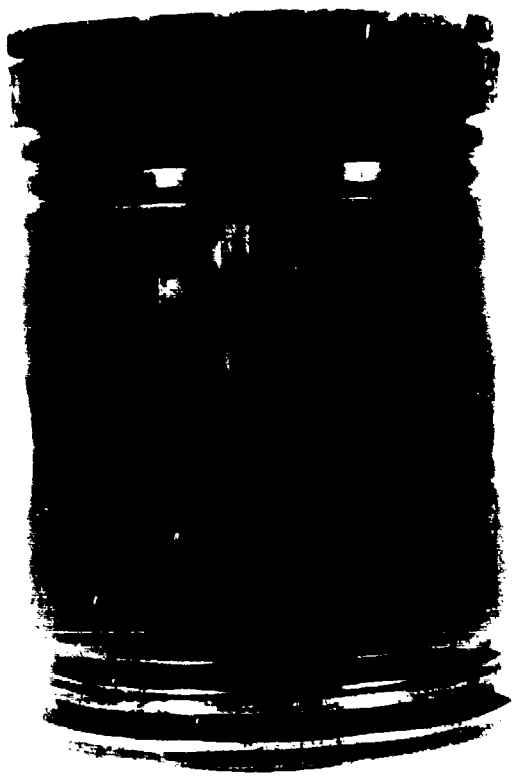
*Cylinder 2-Right had the most scuffing
Piston 2-Right had the highest Weighted Total Deposits (WTD) rating

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L



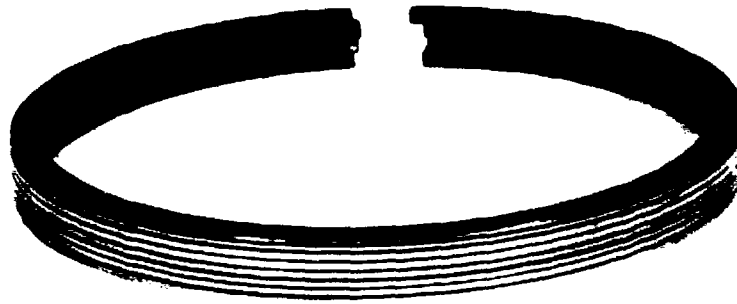
3-Right Thrust

CONDITION OF PISTON AND CYLINDER
6V-53T TEST 9
Lubricant: AL-9249-L

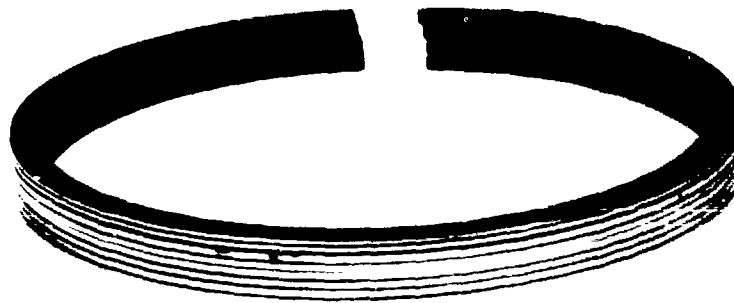


3-Right Anti-Thrust

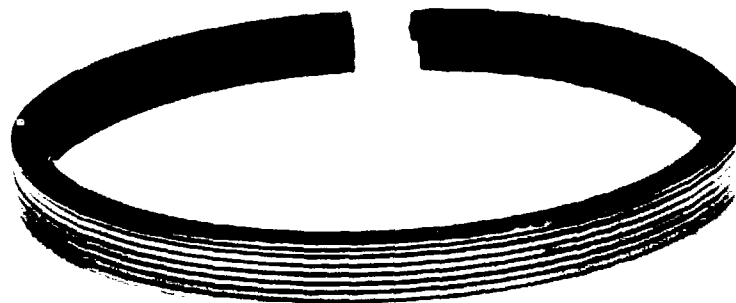
CONDITION OF PISTON RINGS
6V-53T TEST 9
Lubricant: AL-9249-L



1-Left



2-Left



3-Left

CONDITION OF PISTON RINGS
6V-53T TEST 9
Lubricant: AL-9249-L



1-Right



2-Right



3-Right

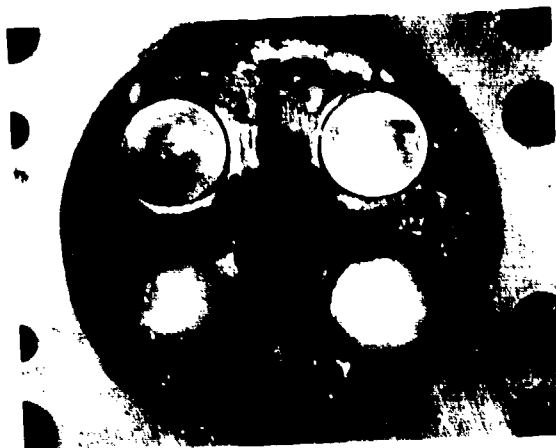
CONDITION OF CYLINDER HEADS
6V-53T TEST 9
Lubricant: AL-9249-L



1-Left



2-Left



3-Left

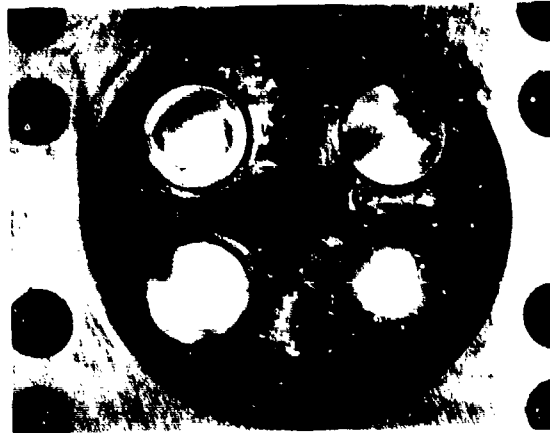
CONDITION OF CYLINDER HEADS

6V-53T TEST 9

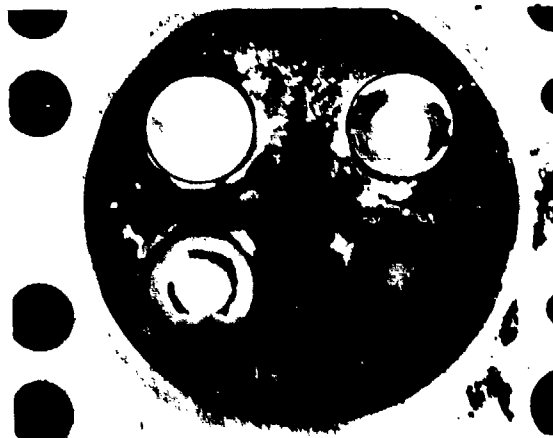
Lubricant: AL-9249-L



1-Right



2-Right



3-Right

APPENDIX H

ENGINE-LUBRICANT COMPATIBILITY TEST #1

210-HOUR WHEELED-VEHICLE CYCLE

USING LD 465 DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
210-HOUR WHEELED-VEHICLE CYCLE
USING LD 465 DIESEL ENGINE

Test Lubricant: AL-6855-L
Test Fuel: AL-7791-F
Engine Test Number: 1
Date Completed: 15 December 1978

Conducted for

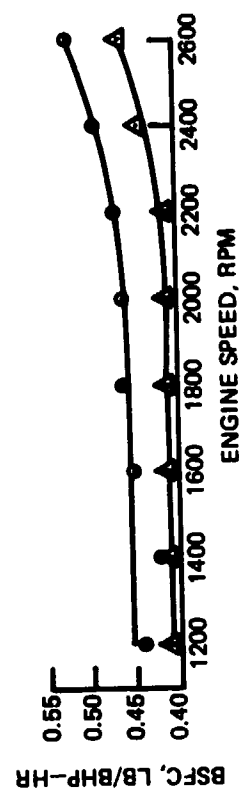
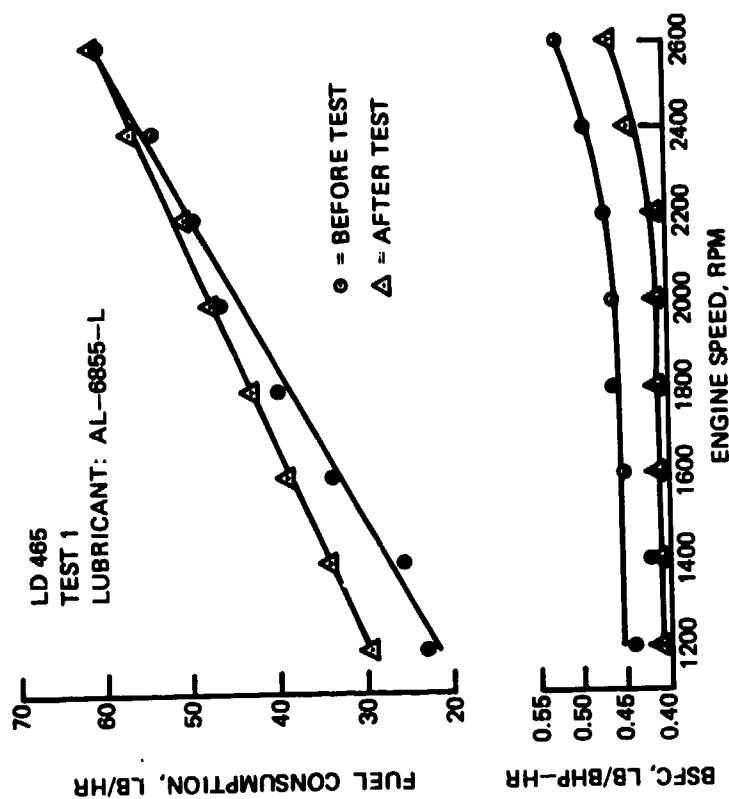
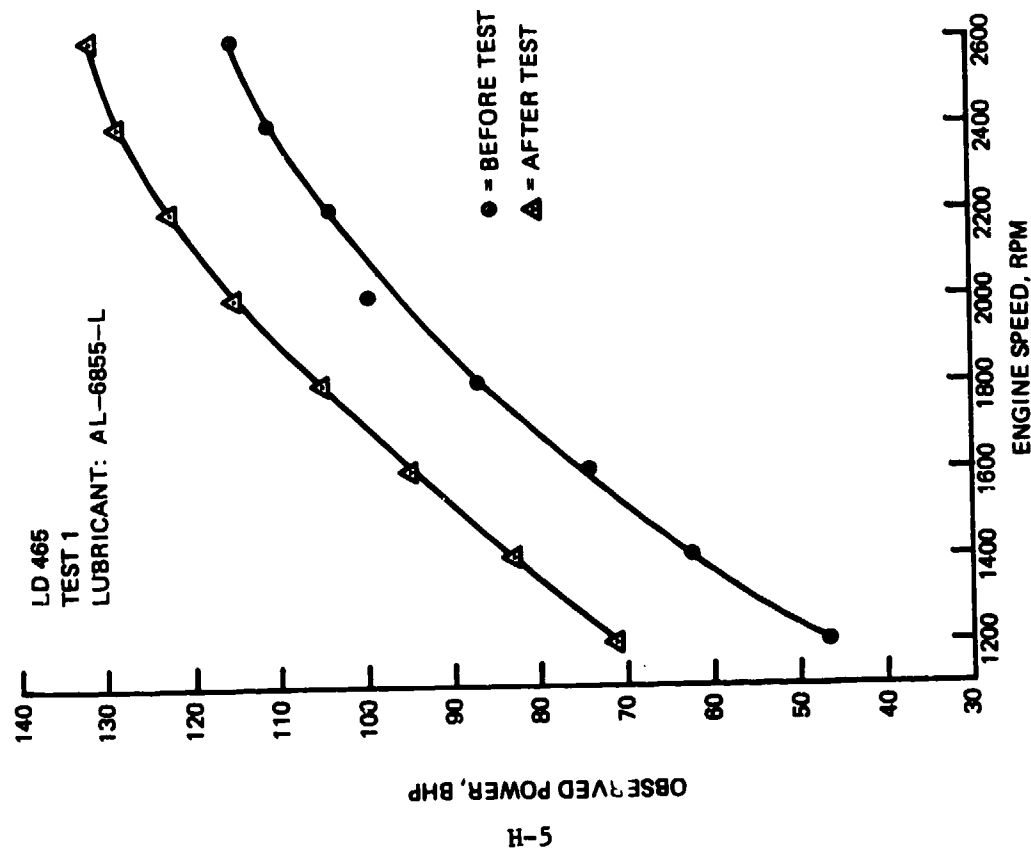
U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

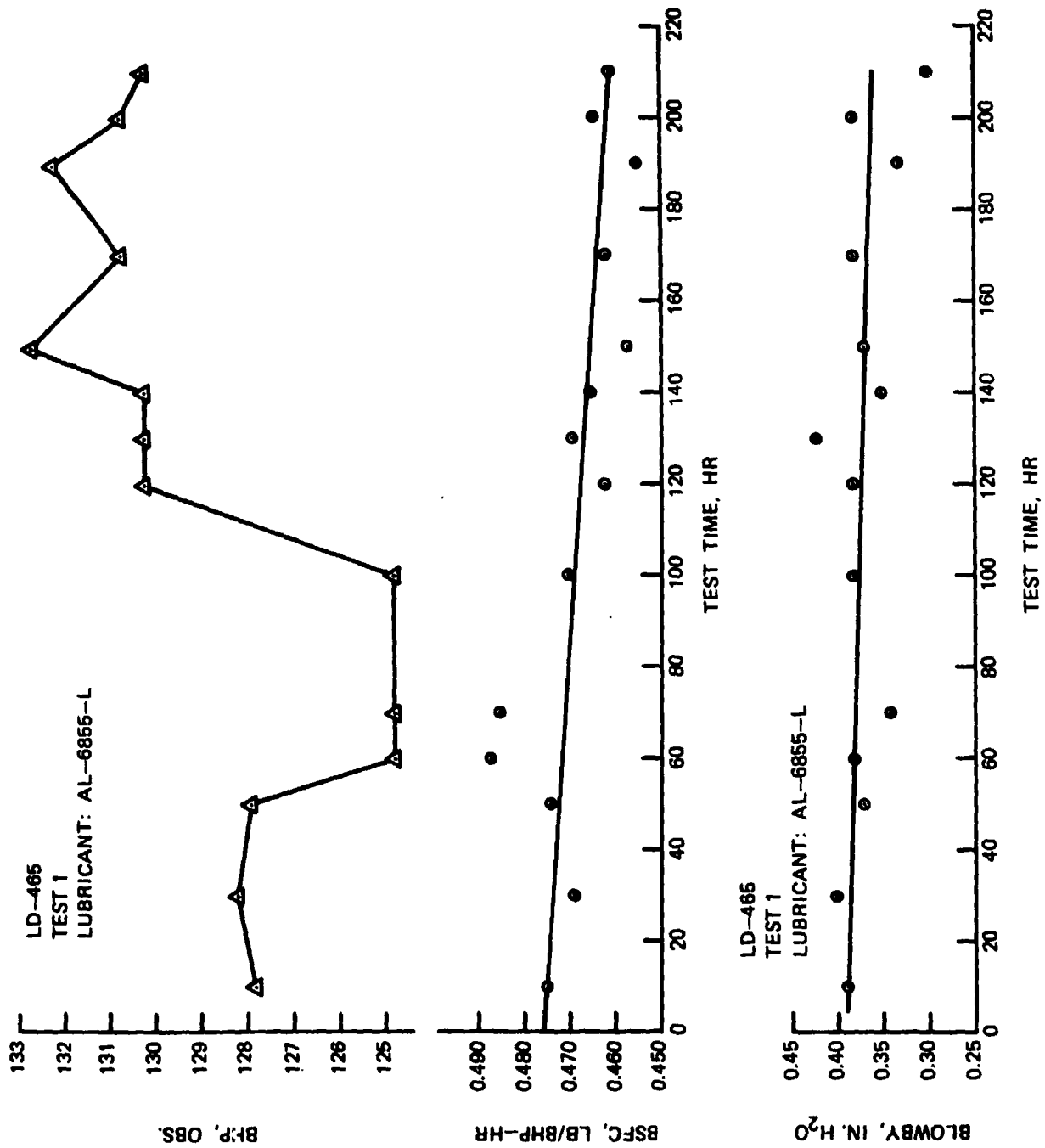
by

U.S. Army Fuels & Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

LD-465
 TEST 1
 LUBRICANT: AL-6855-L
 SUMMARY OF OPERATING DATA

	POWER MODE			IDLE MODE
	MIN	AVE	MAX	AVE
Engine Speed, rpm.	2599	2601	2606	836
Engine Torque, ft-lb	251	260	268	13
Fuel Consumption lb/hr	58.4	60.4	61.5	4.1
BHP (Observed)	124	129	133	2.1
BSFC (Observed)	.471	.468	.462	1.9
<u>Temperatures, °F</u>				
Exhaust Manifold	1250	1280	1330	163
Cooling Water In	167	170	174	97
Cooling Water Out	177	180	183	101
Oil Sump	210	216	223	122
Air In	70	94	128	75
<u>Pressures</u>				
Fuel Transfer Pump, psi	65	72	75	39
Oil Gallery, psi	33	36	38	32
Intake Vacuum, in. H ₂ O	3.2	3.3	3.6	0.4
Exhaust Vacuum, in. Hg	0.8	1.1	1.6	0.0





LD-465
TEST 1
BUILD UP ENGINE MEASUREMENTS

	INCHES			
	MIN	MAX	AVE	SPECIFIED LIMITS
Cylinder Liners (Installed)				
Inside Diameter	4.5625	4.5646	4.5635	4.5630-4.5645
Out-Of-Round	.0001	.0022	.0006	.0015 Max
Piston Skirt Diameter	4.5559	4.5562	4.5560	4.5570-4.5580
#1 Ring				
End Gap	.025	.028	.026	.025-.035
#2 Ring				
End Gap	.025	.030	.027	.025-.035
#3 Ring				
End Gap	.020	.022	.021	.025-.035
Side Clearance	.0035	.0035	.0035	.0025-.0045
#4 Ring				
End Gap	.015	.022	.020	.013-.028
Side Clearance	.0010	.0015	.0015	.0010-.0035

LD-465
TEST 1
LUBRICANT: AL-6855-L

OIL CONSUMPTION (LB)

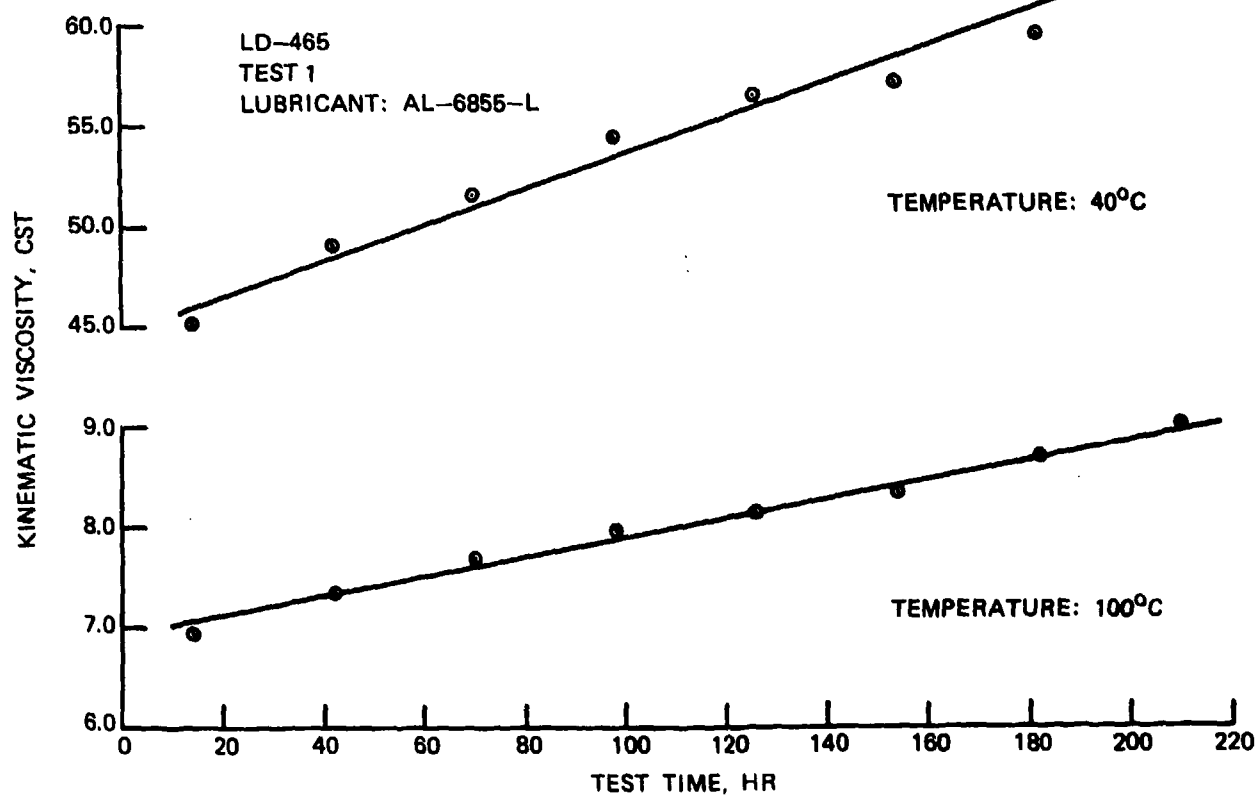
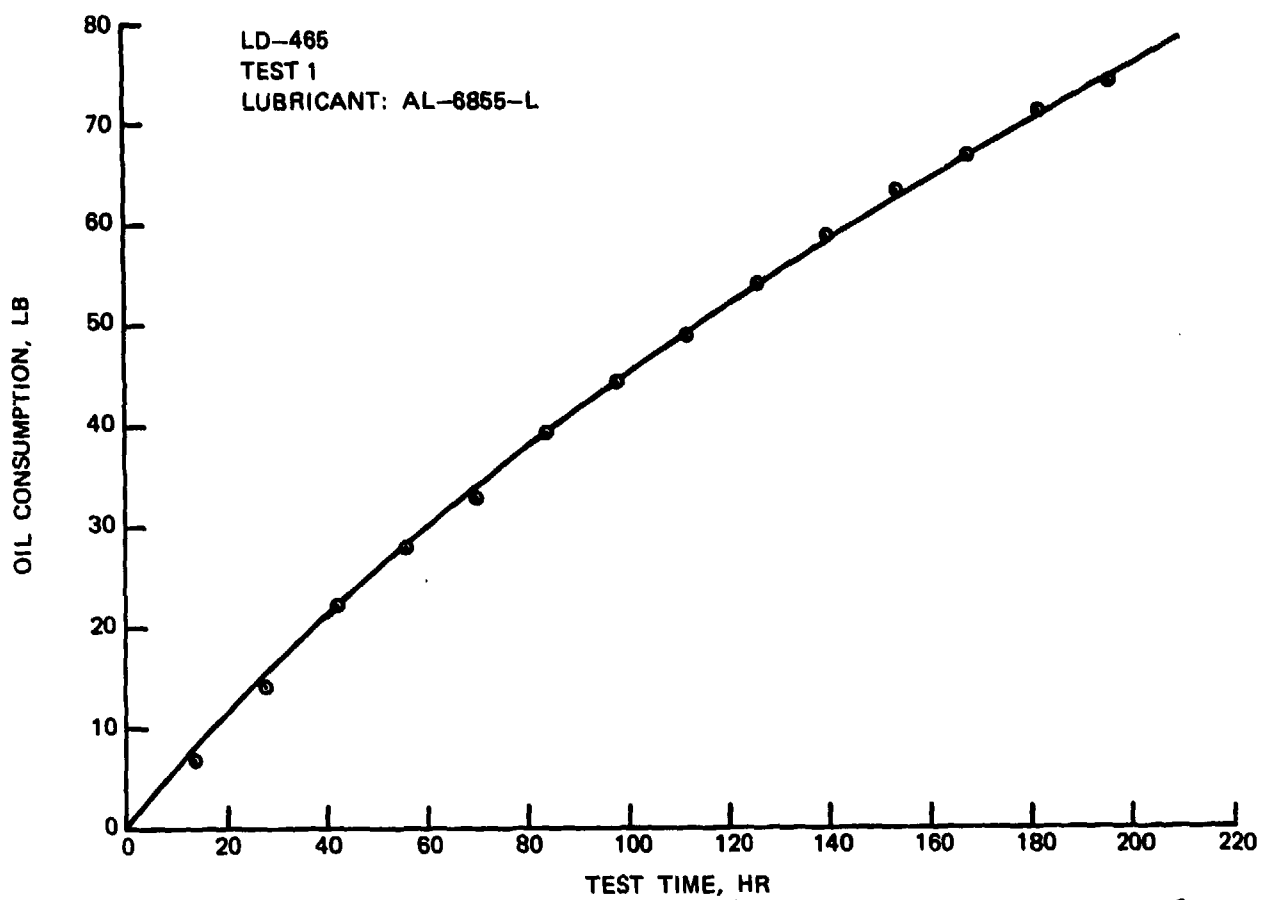
<u>TEST HRS</u>	<u>OIL CONSUMED</u>	<u>TOTAL OIL CONSUMED</u>
14	6.76	6.76
28	6.82	13.58
42	8.08	21.66
56	5.79	27.45
70	5.28	32.73
84	6.48	39.21
98	5.04	44.25
112	4.50	48.75
126	5.08	53.83
140	4.80	58.63
154	4.36	62.99
168	3.48	66.47
182	4.51	70.98
196	2.88	73.86

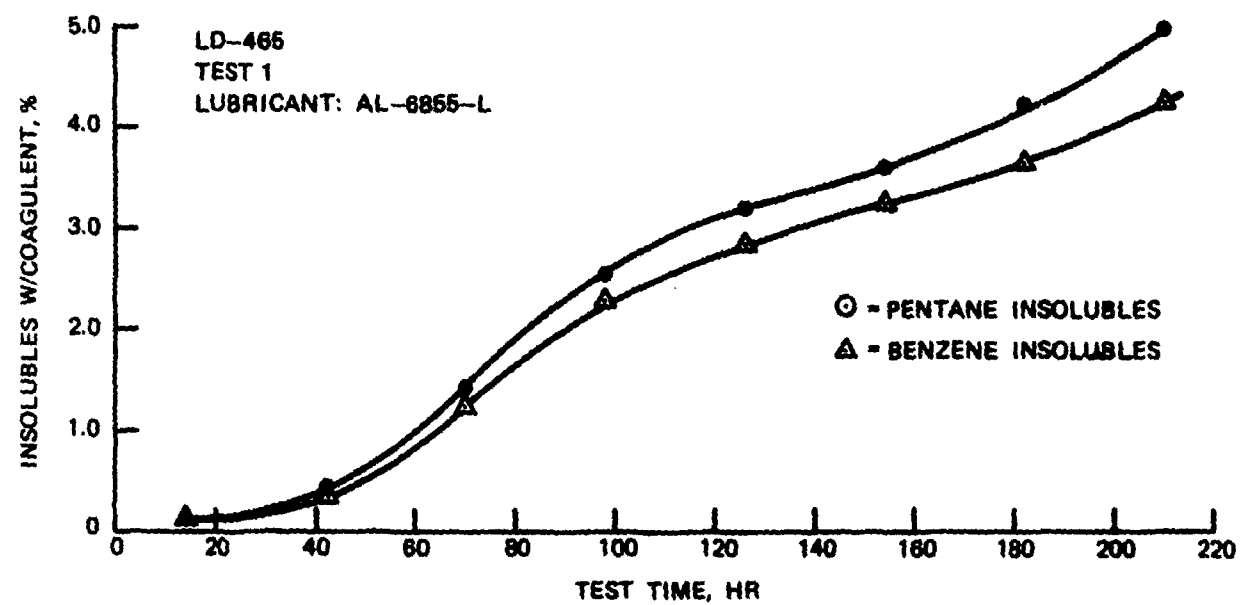
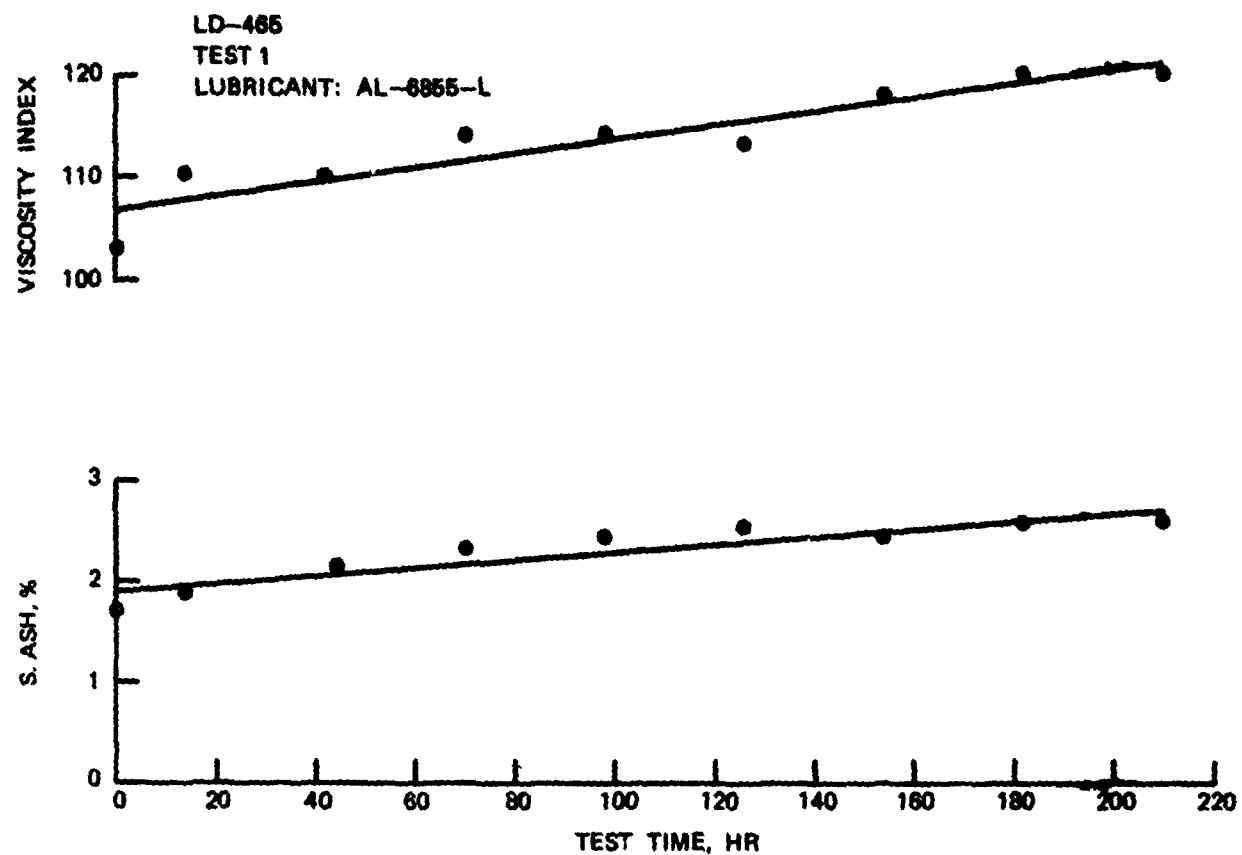
LD-465
TEST 1
LUBRICANT: AL-6855-L

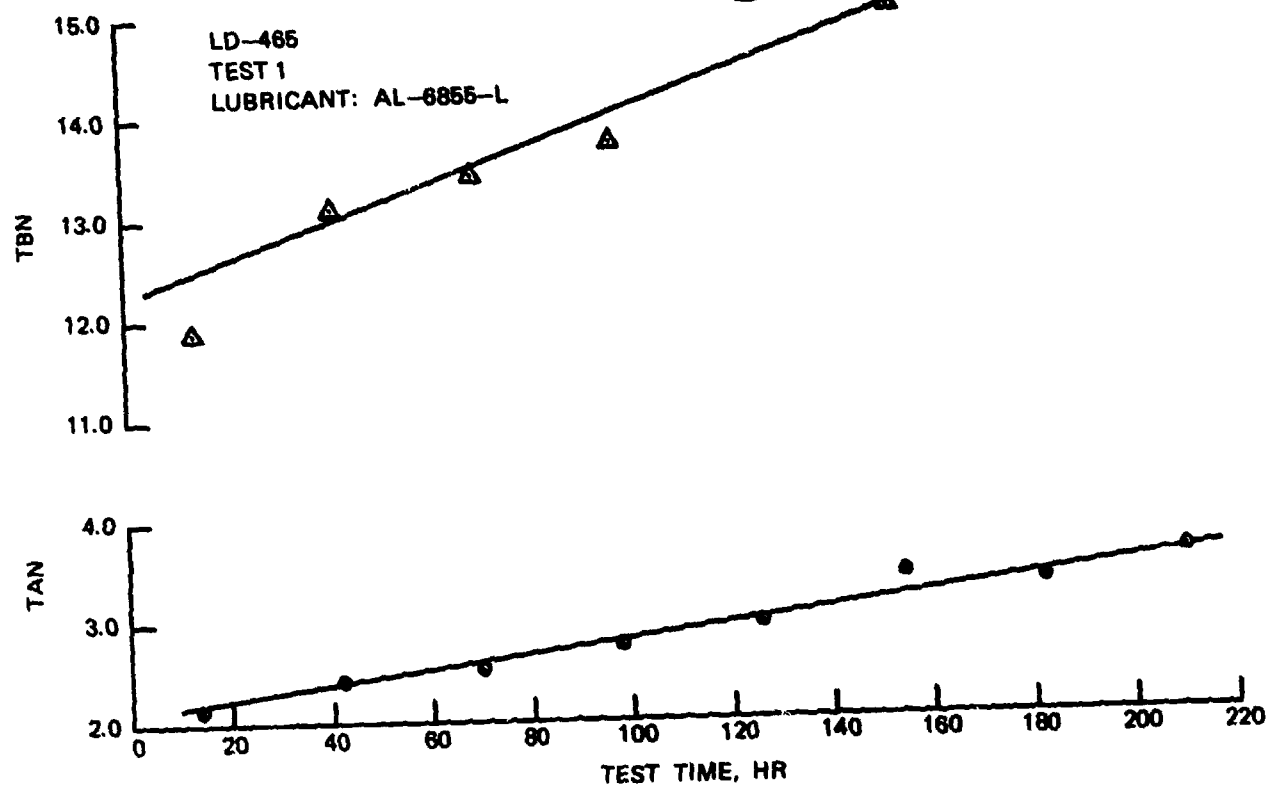
LUBRICANT ANALYSIS

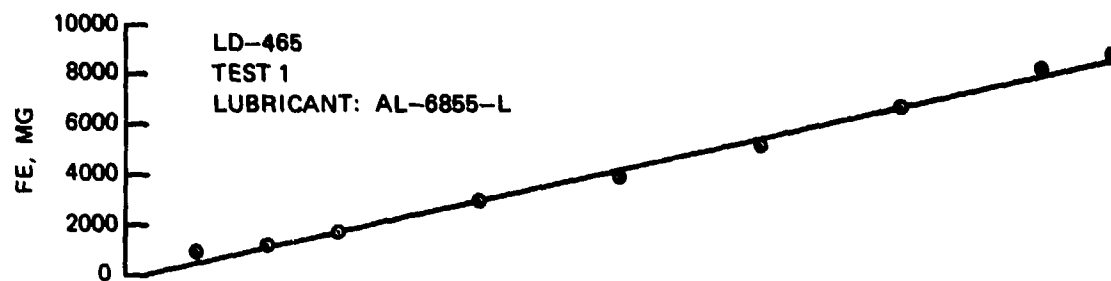
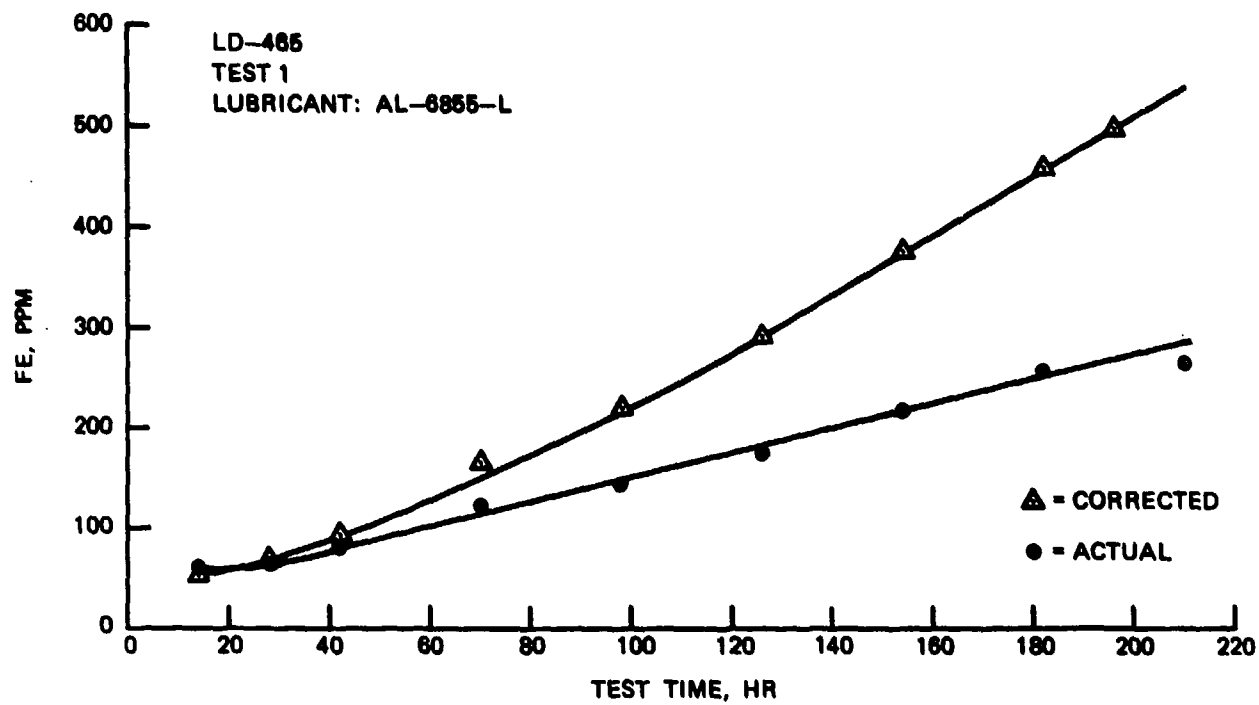
TEST TIME (HRS)

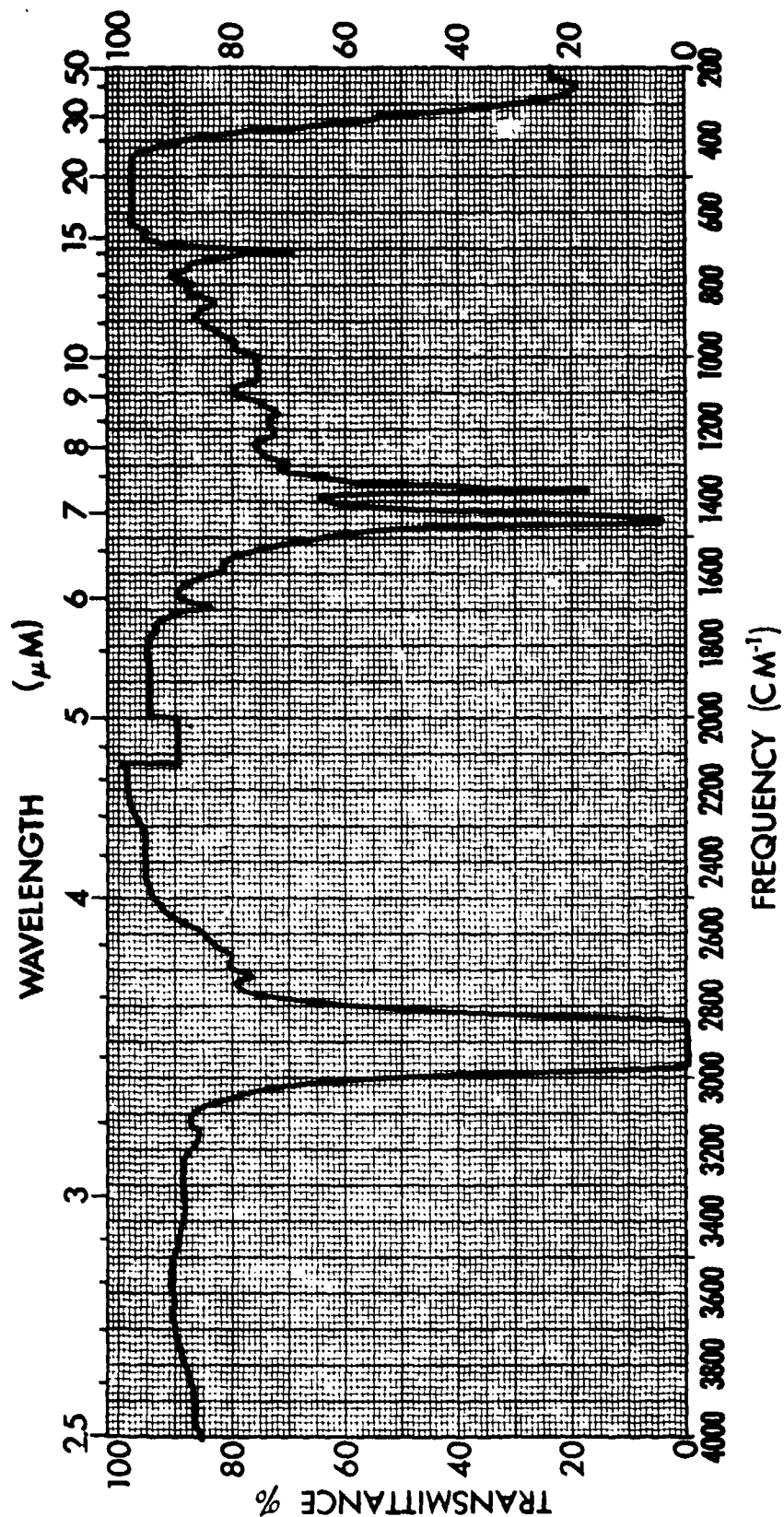
ASTM TEST METHOD	NEW OIL	14	42	70	98	126	154	182	210
		<u>1594</u>	<u>1595</u>	<u>1596</u>	<u>1597</u>	<u>1598</u>	<u>1599</u>	<u>1614</u>	<u>1615</u>
I.R. Trace No.		45.10	49.09	51.48	54.28	56.38	57.0	59.4	62.6
K. Vis., (Cs) @ 40°C		6.94	7.33	7.68	6.95	8.14	8.34	8.68	9.0
K. Vis., (Cs) @ 100°C		110	110	114	114	113	118	120	120
V.I.		2.14	2.40	2.50	2.71	2.93	3.38	3.31	3.55
TAN		11.86	13.09	13.39	13.70	15.13	15.0	15.6	15.1
TBN		1.88	2.13	2.31	2.42	2.62	2.43	2.57	2.59
S. Ash, %		.14	.45	1.41	2.54	3.18	3.60	4.22	4.97
Pentane Insolubles, w/coag., %		.13	.35	1.24	2.2	2.84	3.22	3.64	4.24
Benzene Insolubles, w/coag., %		50	79	124	143	174	216	257	263
Fe (PPM) by XRF		N.D.							



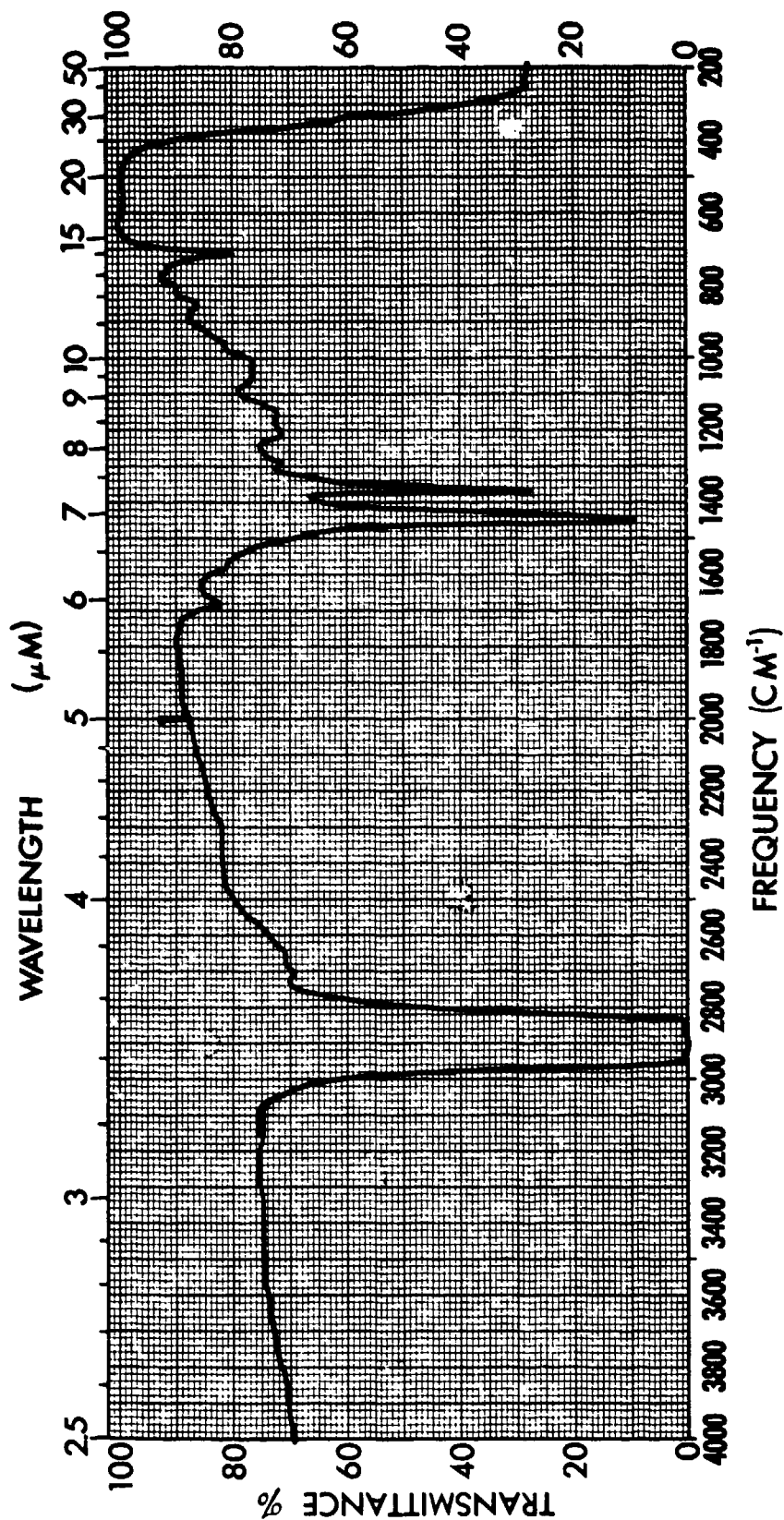




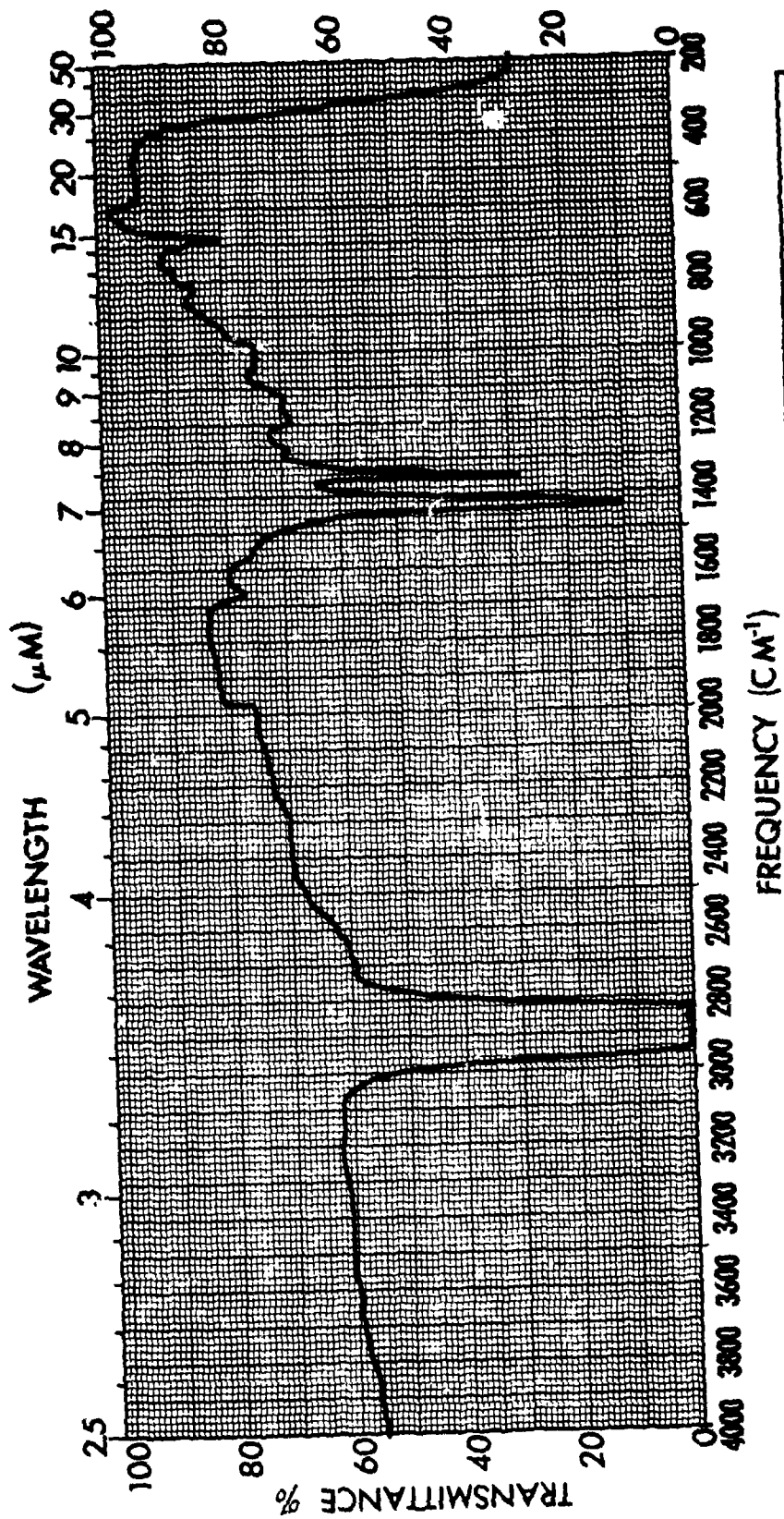




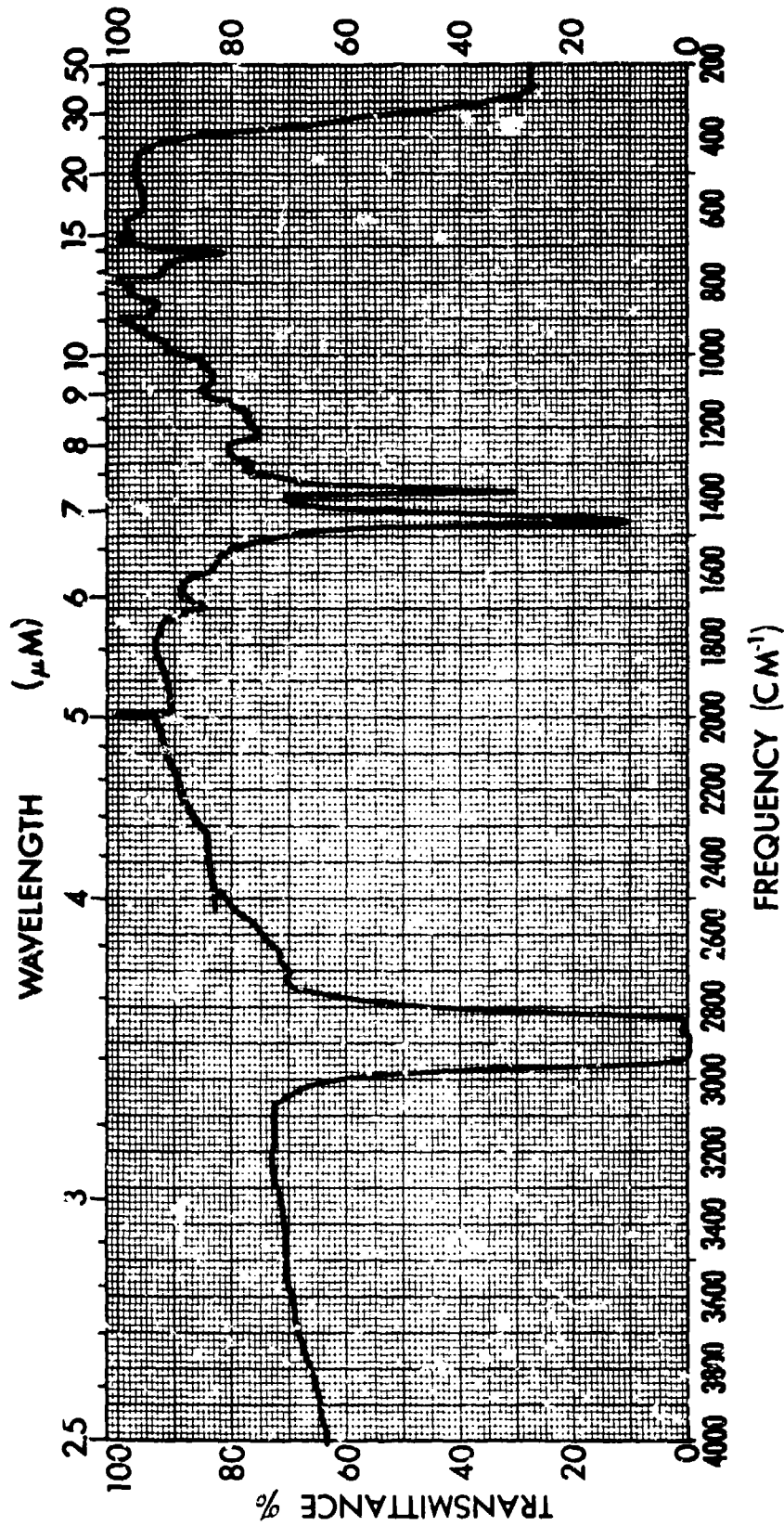
SPECTRUM NO. <u>1594</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6855-L</u>	_____	1. _____	_____
<u>14 Hr</u>	PURITY _____	2. _____	_____
<u>Test 1</u>	PHASE _____	DATE _____	_____
_____	THICKNESS <u>0.025</u>	OPERATOR <u>D. B.</u>	_____



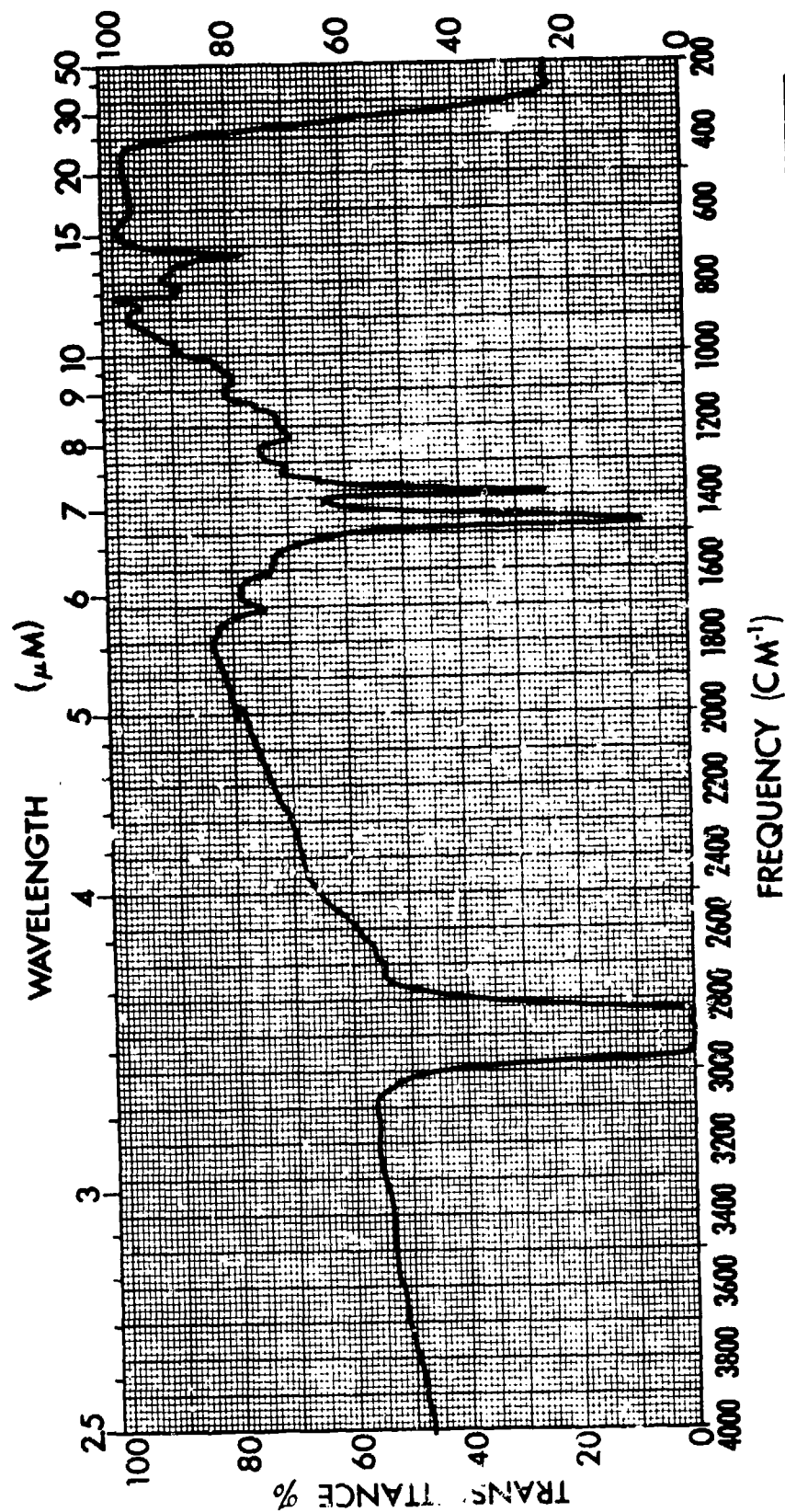
SPECTRUM NO. <u>159.5</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6855-L</u>		1. _____	
<u>42 IR</u>	PURITY _____	2. _____	
<u>TEST 1</u>	PHASE _____	DATE <u>12-11-78</u>	
	THICKNESS <u>0.025</u>	OPERATOR <u>KH</u>	



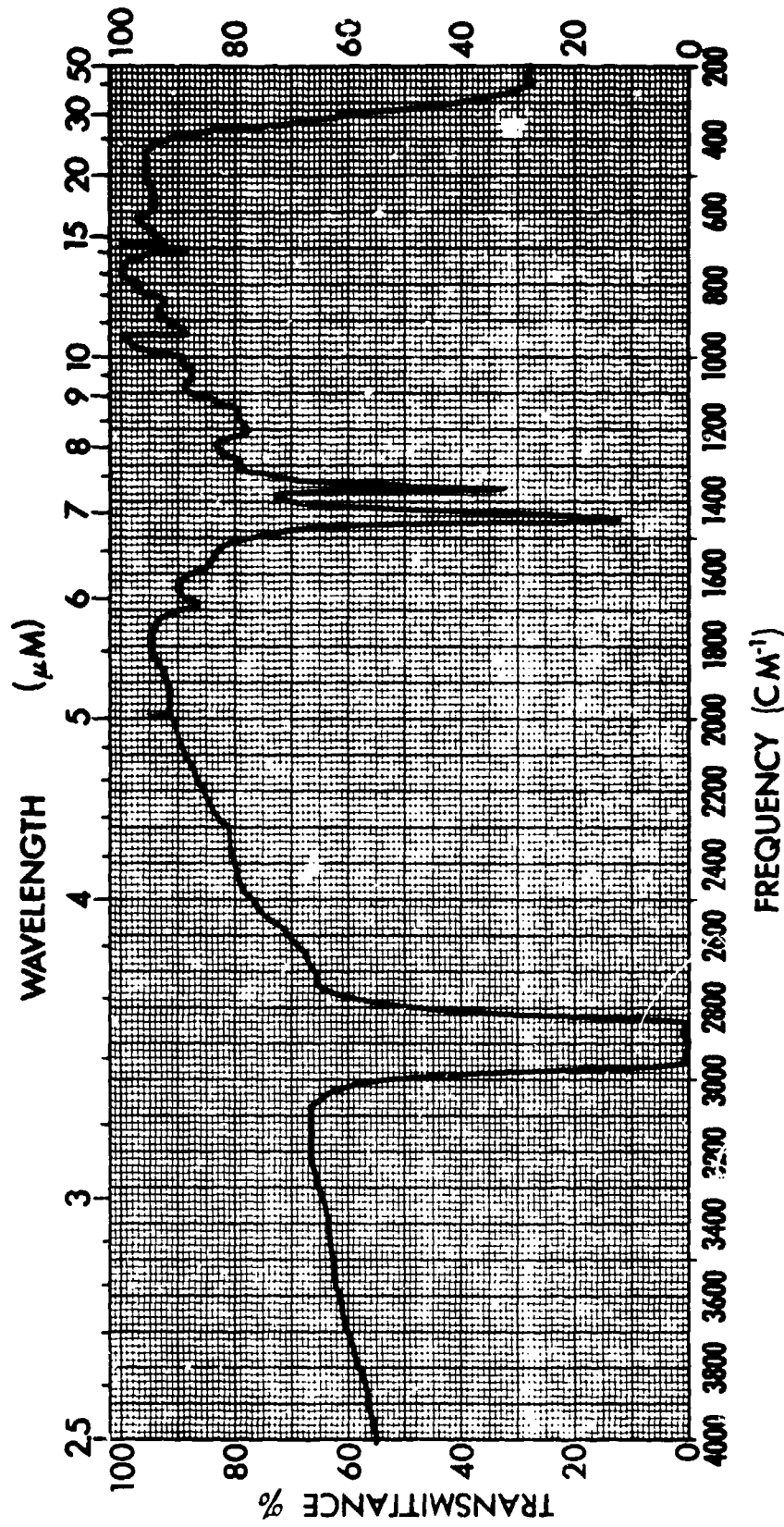
SPECTRUM NO. 1596		ORIGIN		LEGEND		REMARKS	
SAMPLE AL-6855-L				1.			
70 HB		PURITY		2.			
TEST 1		PHASE		DATE 12-11-78			
		THICKNESS 0.025		OPERATOR KH			



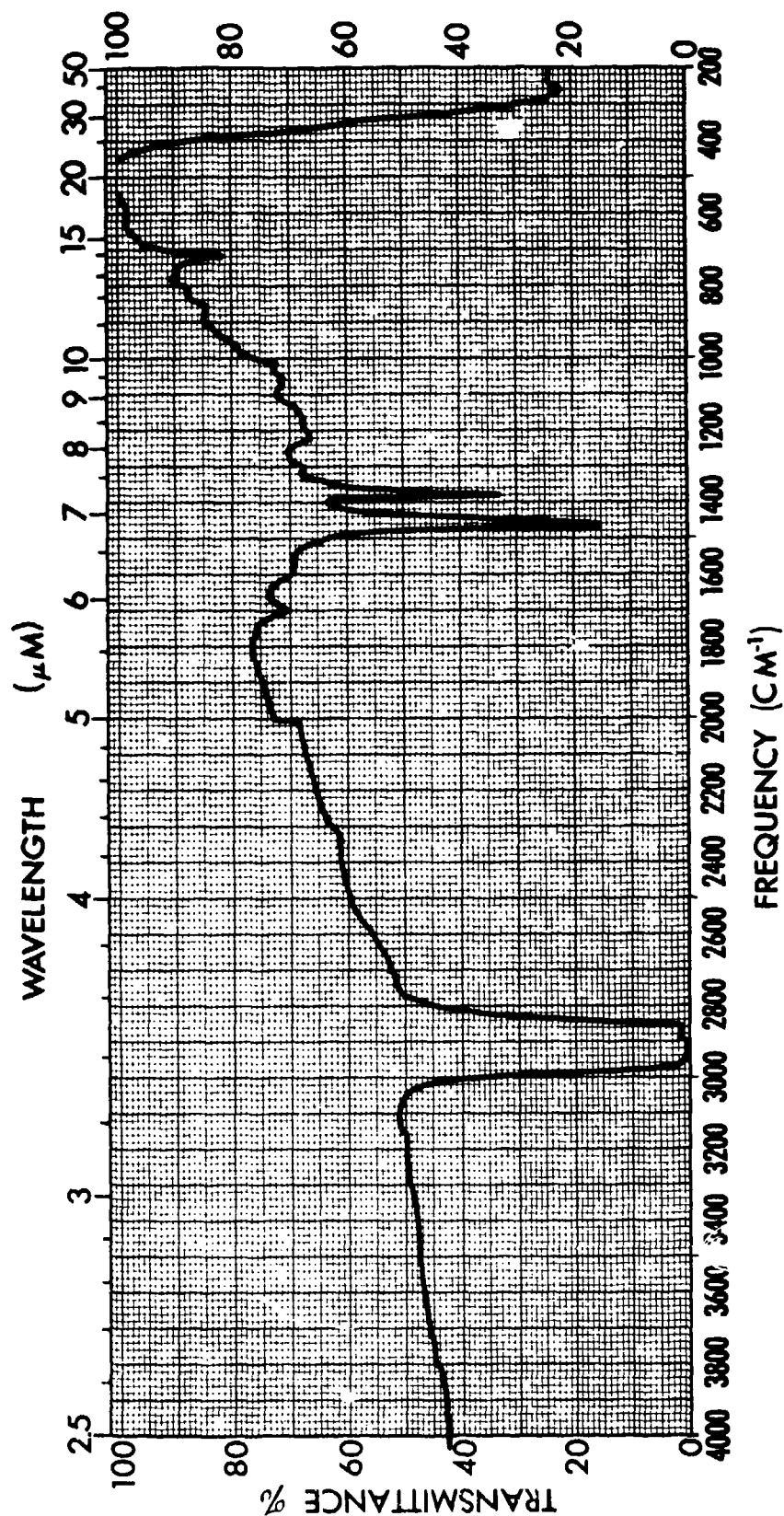
SPECTRUM NO. <u>1597</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6355-L</u>	_____	1. _____	_____
98 HR	PURITY _____	2. _____	_____
TEST 1	PHASE _____	DATE <u>12-11-78</u>	_____
_____	THICKNESS <u>0.025</u>	OPERATOR <u>KH</u>	_____



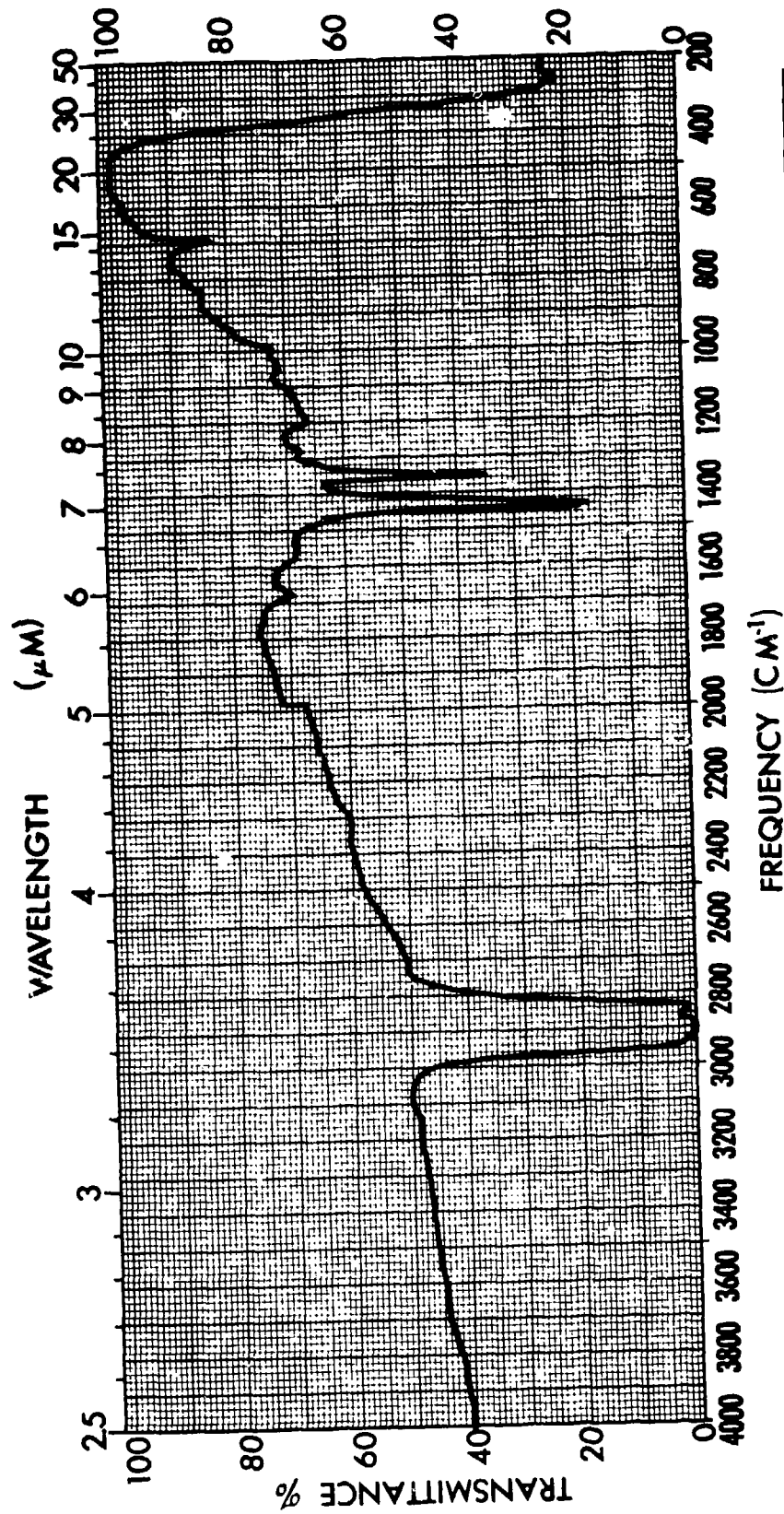
SPECTRUM NO. 1598	ORIGIN	LEGEND	REMARKS
SAMPLE AL-6855-L		1.	
126 HR	PURITY	2.	
TEST 1	PHASE	DATE 12-11-78	
	THICKNESS 0.025	OPERATOR KH	



SPECTRUM NO. 1599	ORIGIN	LEGEND	REMARKS
SAMPLE AL-6855-L		1.	
154 HR	PURITY	2.	
TEST 1	PHASE	DATE 12-12-78	
	THICKNESS 0.025	OPERATOR KH	



SPECTRUM NO. <u>1614</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6855-L</u>	1. _____	2. _____	
<u>184 HR</u>	PURITY _____	DATE <u>12-27-78</u>	
<u>Test 1</u>	PHASE _____	OPERATOR <u>KB</u>	
	THICKNESS <u>0.015</u>		



SPECTRUM NO. 1615	ORIGIN	LEGEND	REMARKS
SAMPLE AL-6855-L		1.	
210 HR	PURITY	2.	
TEST 1	PHASE	DATE 12-27-78	
	THICKNESS 0.015	OPERATOR KB	

LD-465
TEST 1
LUBRICANT: AL-6855-L
WEAR MEASUREMENTS

		CYLINDER LINER BORE DIAMETER (INCHES)					
		LONGITUDINAL			TRANSVERSE		
		BEFORE	AFTER	CHANGE	BEFORE	AFTER	CHANGE
1.	TOP	4.5635	4.5638	.0003	4.5628	4.5628	.0000
	CENTER	4.5632	4.5628	-.0004	4.5638	4.5635	-.0003
	BOTTOM	4.5625	4.5624	-.0001	4.5646	4.5643	-.0003
2.	TOP	4.5633	4.5634	.0001	4.5639	4.5638	-.0001
	CENTER	4.5637	4.5633	-.0004	4.5641	4.5640	-.0001
	BOTTOM	4.5640	4.5635	-.0005	4.5638	4.5641	.0003
3.	TOP	4.5629	4.5629	.0000	4.5635	4.5635	.0000
	CENTER	4.5630	4.5627	-.0003	4.5636	4.5635	-.0001
	BOTTOM	4.5633	4.5630	-.0003	4.5638	4.5636	-.0002
4.	TOP	4.5633	4.5633	.0000	4.5635	4.5636	.0001
	CENTER	4.5634	4.5631	-.0003	4.5635	4.5633	-.0002
	BOTTOM	4.5634	4.5631	-.0003	4.5635	4.5634	-.0001
5.	TOP	4.5626	4.5629	.0003	4.5641	4.5643	.0002
	CENTER	4.5628	4.5627	-.0001	4.5639	4.5643	.0004
	BOTTOM	4.5633	4.5631	-.0002	4.5642	4.5642	.0000
6.	TOP	4.5636	4.5639	.0003	4.5635	4.5636	.0001
	CENTER	4.5636	4.5635	-.0001	4.5637	4.5635	-.0002
	BOTTOM	4.5638	4.5636	-.0002	4.5635	4.5634	-.0001

LD-465
TEST 1
LUBRICANT: AL-6855-L
WEAR MEASUREMENTS

Piston Ring End Gap (inches)

Ring Number*	Piston Number					
	1	2	3	4	5	6
1. Before Test	.028	.025	.028	.025	.025	.025
After Test	.024	.030	.028	.028	.025	.025
Change	-.004	.005	.000	.003	.000	.000
2. Before Test	.028	.025	.028	.028	.030	.025
After Test	.030	.028	.028	.030	.028	.025
Change	.002	.003	.000	.002	-.002	.000
3. Before Test	.020	.021	.020	.021	.022	.021
After Test	.025	.025	.022	.024	.025	.025
Change	.005	.004	.002	.003	.003	.004
4. Before Test	.019	.022	.020	.022	.020	.015
After Test	.022	.022	.022	.022	.025	.024
Change	.003	.000	-.002	.000	.005	.009

* From Top of Piston

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 1

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-6855-L

RATER E.L. DATE 12-20-78
 LABORATORY TEST NUMBER 1
 STAND NO. 6 ENGINE NO. LD 465-3904343
 FUEL CAT I-H

TEST HOURS _____															STAND NO. 6 _____ ENGINE NO. LD 465-3904343															NO. 1 GROOVE, VOLUME-%		138.125																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
TEST LABORATORY YAFRL															CAT I-H															PISTON WTD* RATING																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 2

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFLRL
 LUBRICANT AL-6855-L

RATER E.L. DATE 12-20-78
 LABORATORY TEST NUMBER 1
 STAND NO. 6 ENGINE NO. LD 465-3904343
 FUEL CAT 1-H

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								NO. 1 GROOVE, VOLUME-%	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	138.885
CARBON	HC	1.00																	
	MHC	0.75	10	7.50						15	11.25								
	MC	0.50	90	45.00						60	30.00								
	LC	0.25								25	13.75	10	2.50						
	VLC	0.15																	
CARBON RATING		52.50								55.00	2.50								
LACQUER	PL	0.100		60	6.00						15	1.50							
	PR L	0.075		40	3.00	100	7.50				5	.375							
	AL	0.050									70	3.50							
	LAL	0.025														100	2.50	100	2.50
	VLAL	0.010															100	1.00	
LACQUER RATING			9.00	7.50	1.00						5.375	2.50	1.00						
CLEAN		0																	
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		52.50	9.00	7.50	1.00					55.00	7.875	2.50	1.00					1.00	2.50

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 3

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-6855-I

RATER E.L. DATE 12-20-78
 LABORATORY TEST NUMBER 1
 STAND NO. 6 ENGINE NO. LD 465
 FUEL CAT 1-H

STAND NO. 6		ENGINE NO. LD 463		NO. 1 GROOVE, VOLUME %		PISTON WTD* RATING		117.25							
FUEL CAT 1-H															
TEST LABORATORY AFLRL		AL-6855-L													
LUBRICANT															
DEPOSIT TYPE		DEPOSIT FACTOR		GROOVES				LANDS				UNDER-CROWN			
				NO. 1		NO. 2		NO. 3		NO. 4					
				AREA-%		DEMERIT		AREA-%		DEMERIT		AREA-%		DEMERIT	
HC		1.00													
MHC		0.75													
MC		0.50													
LC		0.25		100		25.00									
VLC		0.15													
CARBON RATING				25.00						52.50					
BL		0.100				100		10.00		100		10.00		5	
DBrL		0.075												5.00	
AL		0.050										95		7.75	
LAL		0.025								100		2.50		100	
VLAL		0.010												2.50	
RL		0.001												100	
LACQUER RATING						10.00		10.00		2.50		9.75		2.50	
CLEAN		0												2.50	
ZONAL RATING															
LOCATION FACTOR															
WEIGHTED RATING		25.00		10.00		10.00		2.50		52.50		9.75		2.50	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE <u>WheelLed</u>	RATER <u>E.L.</u>	PISTON NO. <u>4</u>
TEST HOURS <u>210</u>	LABORATORY TEST NUMBER <u>1</u>	
TEST LABORATORY <u>AFRL</u>	STAND NO. <u>6</u> ENGINE NO. <u>465-3904343</u>	
LUBRICANT <u>AL-6855-L</u>	FUEL <u>CAT 1-H</u>	

NO. 1 GROOVE, VOLUME-%	UNDER-CROWN
PISTON WTD* RATING	142.875

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN															
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4																	
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT			AREA-%	DEMERIT												
CARBON			HC	1.00																														
	MHC	0.75	15	11.25																														
	MC	0.50	75	37.50																														
	LC	0.25	10	2.50																														
	VLC	0.15																																
	CARBON RATING		51.25										50.00																					
LACQUER			BL	0.100													5	5.00	5	5.00														
			DBrL	0.075			100	7.50										85	6.375															
			AL	0.050															10	.50	95	4.75				100	5.00							
			LAL	0.025						100	2.50	100	2.50																					
			VLAL	0.010																														
			RL	0.001																														
LACQUER RATING			7.50										2.50										2.50										5.00	
CLEAN			0																															
ZONAL RATING																																		
LOCATION FACTOR																																		
WEIGHTED RATING			51.25		7.50		2.50		2.50		2.50		50.00		11.875		9.75		2.50						5.00									

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 5

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFLRL
 LUBRICANT AL-6855-L

RATER E.L. DATE 12-20-78
 LABORATORY TEST NUMBER 1
 STAND NO. 6 ENGINE NO. 465-3904343
 FUEL CAT 1-H

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				UNDER-CROWN	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1 GROOVE, VOLUME-%	PISTON WTD* RATING
		AREA-% DEPOSIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT		
CARBON	HC	1.00									
	MHC	0.75	40	30.00		50	25.00				
	MC	0.50	60	30.00		50	12.50	10	2.50		
	LC	0.25									
	VLC	0.15									
CARBON RATING		60.00				27.50	2.50				
LACQUER	BL	0.100									
	DBrL	0.075									
	AL	0.050									
	LAL	0.025									
	VLAL	0.010									
LACQUER RATING											
CLEAN	0										
ZONAL RATING											
LOCATION FACTOR											
WEIGHTED RATING		60.00	7.50	7.50	7.50	27.50	5.00	2.50	2.50	5.00	125.00

*WEIGHTED TOTAL DEPOSITS

APPENDIX C COMPUTATION SHEET FOR PISTON RATING

PISTON NO. _____ 6

9

TEST PROCEDURE 210 Wheel
TEST HOURS _____
TEST LABORATORY AFRL
LUBRICANT AL-6855-L

DRIVER E.L. DATE 1
 LABORATORY TEST NUMBER LD 465-3904343
 STAND NO. 6 ENGINE NO. CAT 1-H
 FUEL

LABORATORY TEST NUMBER										LD 465-3904343													
STAND NO. 6										ENGINE NO. CAT 1-H													
FUEL																							
EST PROCEDURE 210																							
EST HOURS																							
EST LABORATORY										AL-6855-L													
LUBRICANT																							
DEPOSIT TYPE		DEPOSIT FACTOR		GROOVES								LANDS								UNDER-CROWN			
				NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4					
				AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
14C		1.00												10	7.50								
MHC		0.75		100	75.00									80	40.00								
MC		0.50												10	2.50								
LC		0.25														15	2.25						
VLC		0.15																					
CARBON RATING				75.00										14.00			2.25						
BL		0.100				100	10.0											5	.50				
DBrL		0.075																				100	5.00
AL		0.050						100	5.00	100	5.00					85	4.25			95	2.375	100	2.50
LAL		0.025																					
VLAL		0.010																					
RL		0.001																					
LACQUER RATING						10.00		5.00	5.00								4.25		2.875		2.50		5.00
CLEAN		0																					
ZONAL RATING																							
LOCATION FACTOR																							
WEIGHTED RATING				75.00		10.00		5.00		5.00				14.00		6.50		2.875		2.50			5.00

*WEIGHTED TOTAL DEPOSITS

RING DEPOSITS

Test No. 1 Cell 6

Serial No. 3904343

Date 12-21-78

Engine Model Continental LD-465

Lubricant AL-68-55-L

Observer Lyons

Fuel CAT 1-H

Cylinder Number		1		2		3		4		5		6	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Piston Ring	Top	1	0	0	0	0	10	0	50	0	0	0	25
		2	0	0	0	0	5	0	0	0	5	0	5
		3	0	0	0	0	95	0	100	0	100	0	90
		4											
ID		1	0	0	0	0	100	0	100	0	100	15	85
		2	0	0	0	0	100	0	100	0	100	0	100
		3	0	0	0	0	100	0	100	0	100	0	100
		4											
Bottom		1	0	0	0	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	30	0	30
		3	0	85	0	0	0	0	75	0	75	0	60
		4											

See pages 4, 36 and 37 of Manual. Areas previously rated for carbon, rate 0 for lacquer

RING FACE CONDITION

Engine Model Cont. LD 465 Test No. 1 Cell 6 Serial No. 3904343 Date 12-21-78
 Fuel CAT 1-H Lubricant AL-6855-L Observer Lyons

	Cylinder Number					
	1	2	3	4	5	6
First Ring	N	N	N	N	N	N
Second Ring	N	N	N	N	N	N
Third Ring	N	N	N	N	N	N
Fourth Ring	N	N	N	N	N	N
Oil Ring Slots-% Open	100	100	100	100	100	100

Pages 1 and 2 and 59 through 65 of Manual.

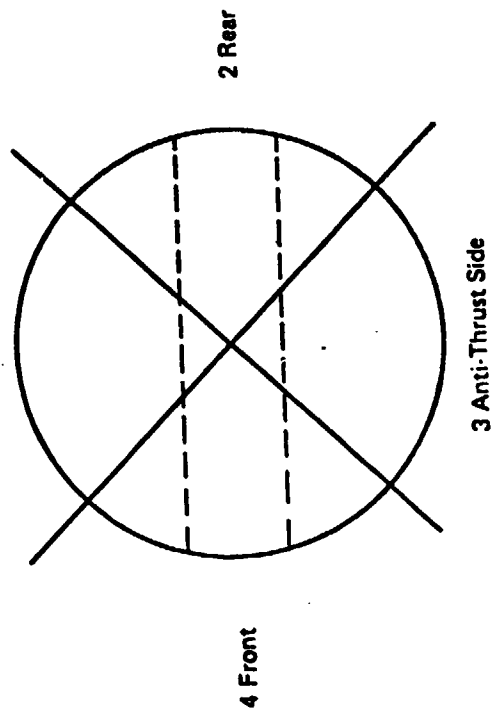
N - Normal

PISTON GROOVE INSIDE DIAMETER - % RING SUPPORTING CARBON

Engine Model Cont. LD 465 Test No. 1 Cell 6 Date 12-21-78
CAI I-H Serial No. 3904343 Observer Lyons
 Fuel _____ Lubricant AL-6855-L

Piston Ring	Quadrant	Piston Number					
		1	2	3	4	5	6
1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0

1 Thrust Side



PISTON SURFACE CONDITION

Engine Model Coast LD 465 Test No. 1 Cell 6 Date 12-21-78
 Fuel CAT 1-H Serial No. 3904343 Observer Lyons
 Lubricant AL-6855-L

	Piston Number					
	1	2	3	4	5	6
Top Land	N	N	N	N	N	N
Skirt	N	N	N	N	N	N
Piston Pin	N	N	N	N	N	N

Pages 1 through 2 and 59 through 65 of Manual.

N = NORMAL

VALVE SURFACE CONDITIONS

Test No. 1 Cell 6

Cont. LD 465

Serial No. 3904343

Date 12-21-78

Engine Model CAT 1-H

Lubricant AL-6855-L

Observer Lyons

	Intake						Exhaust					
	1	2	3	4	5	6	1	2	3	4	5	6
Freedom in Guide	F	F	F	F	F	F	F	F	F	F	F	F
Head	N	N	N	N	N	N	N	N	N	N	N	N
Face	N	N	N	N	N	N	N	N	N	N	N	N
Seat	N	N	N	N	N	N	N	N	N	N	N	N
Stem	N	N	N	N	N	N	N	N	N	N	N	N
Tip	N	N	N	N	N	N	N	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

Tulip Deposit 3.5 4.5 4.5 3.5 4.5 3.0 4.5 .5 .5 .5 .5 .5

F - FREE

N - NORMAL

CYLINDERS

Engine Model Cont. LD 465 Test No. 1 Cell 6 Date 12-21-78
 Fuel CAT 1-H Serial No. 3904343 Observer Lyons
 Lubricant AL-6855-L

		Cylinder Number											
		1		2		3		4		5		6	
Deposits	Cylinder Head	CARB	LACO	CARB	LACO	CARB	LACO	CARB	LACO	CARB	LACO	CARB	LACO
Cylinders	ART	70	10	90	0	70	15	70	15	100	0	70	20
	RTA	0	0	0	0	0	0	0	0	0	0		
	BRT	0	0	0	0	0	0	0	0	0	0		
Surface Condition													
Cylinders	RTA	5% Blaze LT Scratches	10% Glaze LT Scratches	10% Glaze LT Scratches	10% Glaze LT Scratches	10% Glaze LT Scratches	5% Glaze LT Scratches	5% Glaze LT Scratches	10% Glaze LT Scratches	10% Glaze LT Scratches	5% Glaze LT Scratches	5% Glaze LT Scratches	
	BRTA	N		N		N		N		N		N	

Carbon and Ash: Use Volume Factor Pages 5 and 40 through 47 of Manual.

Indicate H, M, or S

Lacquer: Use Pages 4, 36 and 37

For Surface Condition--See Pages 1, 2, 16 through 23 and 54 through 65.

N = NORMAL

SURFACE CONDITION

TEST No. 1 Cell 6

Engine Model Cont. LD 465 Serial No. 3904343 Date 12-21-78
 Fuel CAT 1-H Lubricant AL-6855-L Observer Lyons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing	Wore Thru To Copper	Wore Thru To Copper; Scratched	Wore thru To Copper; Scratched	Medium Wear; Scratched	Wore Thru To Copper; Scratched	Same as Bearing No. 5	
	N	N	N	N	N	N	N
Rod-Bearing	ALL HAVE MEDIUM TO HEAVY WEAR ON THRUST SIDE OF BOTTOM AT PART (All used Bearings)						
-Journal	N	N	N	N	N	N	N
Piston Pin	N	N	N	N	N	N	
Bushing	N	N	N	N	N	N	

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

NOTE: Main bearings and connecting rod bearings all have been run before (replaced all)

N = NORMAL

LD-465
TEST 1
AFTER TEST CONDITION OF CYLINDER HEADS



CYLINDERS 1, 2, AND 3



CYLINDERS 4, 5, AND 6

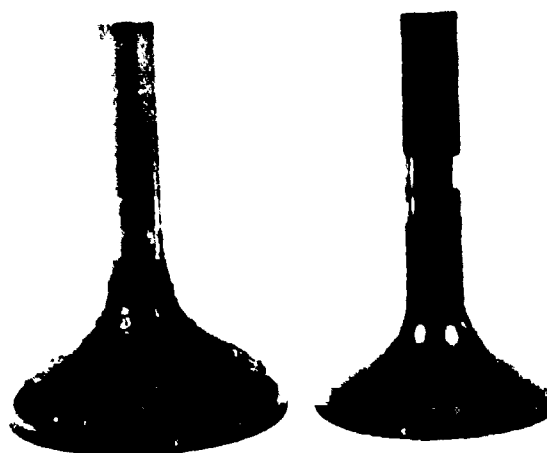
LD-465
TEST 1
AFTER TEST CONDITION OF NO. 1 PISTON AND VALVES



PISTON THRUST SIDE

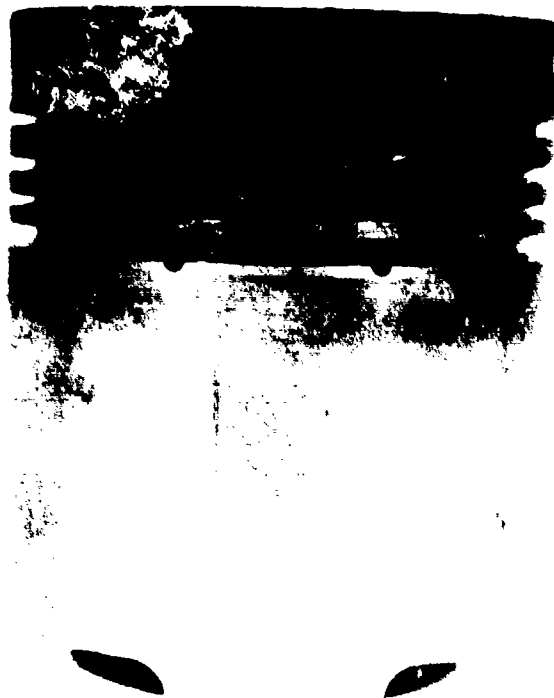


PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

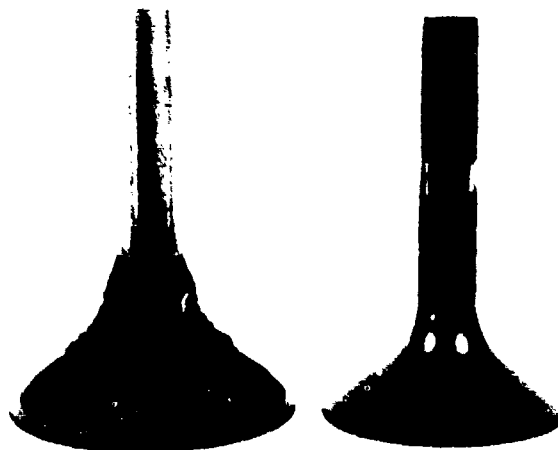
LD-465
TEST 1
AFTER TEST CONDITION OF NO. 2 PISTON AND VALVES



PISTON THRUST SIDE

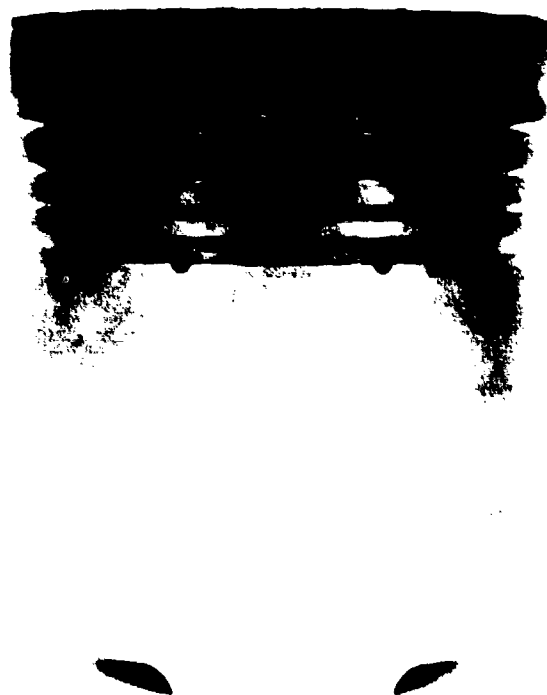


PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

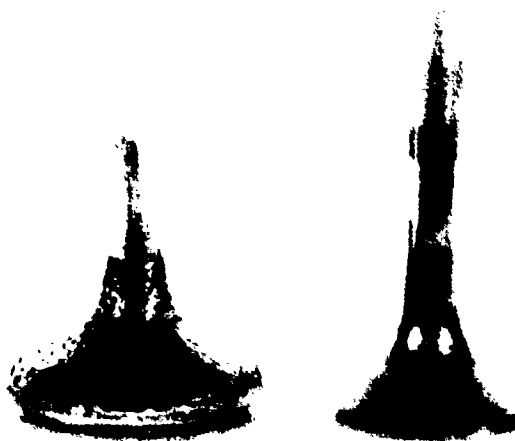
LD-465
TEST 1
AFTER TEST CONDITION OF NO. 3 PISTON AND VALVES



PISTON THRUST SIDE



PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

APPENDIX I

ENGINE-LUBRICANT COMPATIBILITY TEST #2

210-HOUR WHEELED-VEHICLE CYCLE

USING LD 465 DIESEL ENGINE

**ENGINE-LUBRICANT COMPATIBILITY TEST
210-HOUR WHEELED-VEHICLE CYCLE
USING LD 465 DIESEL ENGINE**

**Test Lubricant: AL-6942-L
Test Fuel: AL-7799-F
Engine Test Number: 2
Date Completed: 26 January 1979**

Conducted for

**U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia**

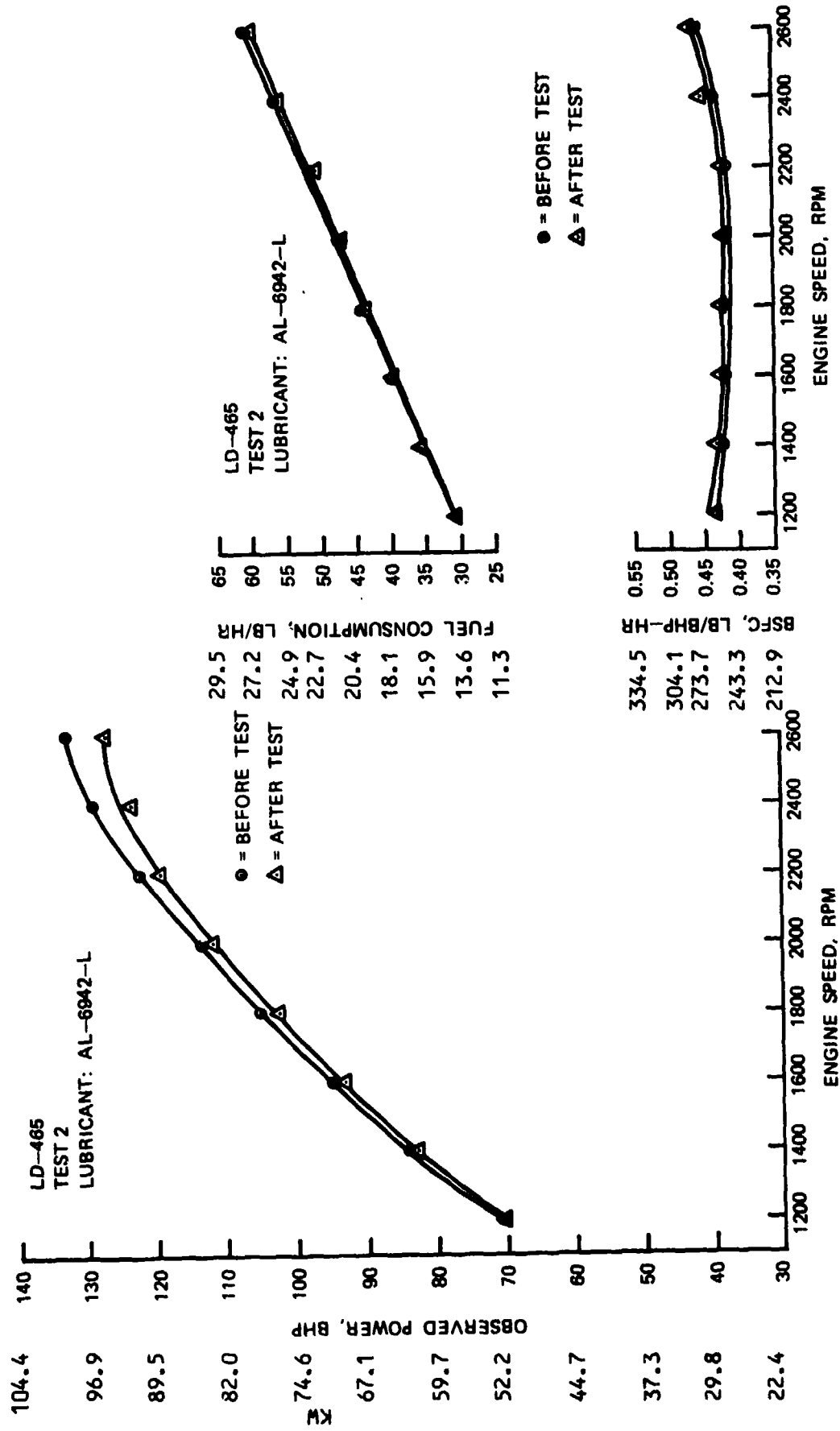
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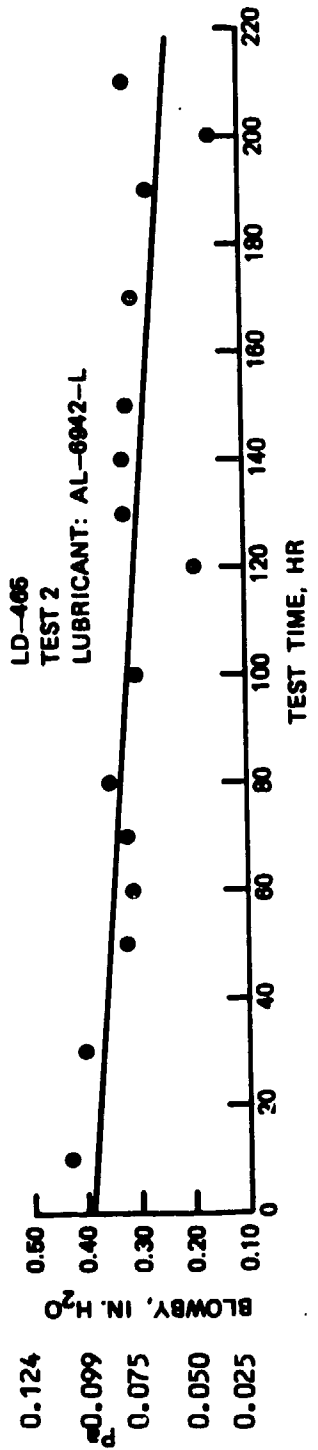
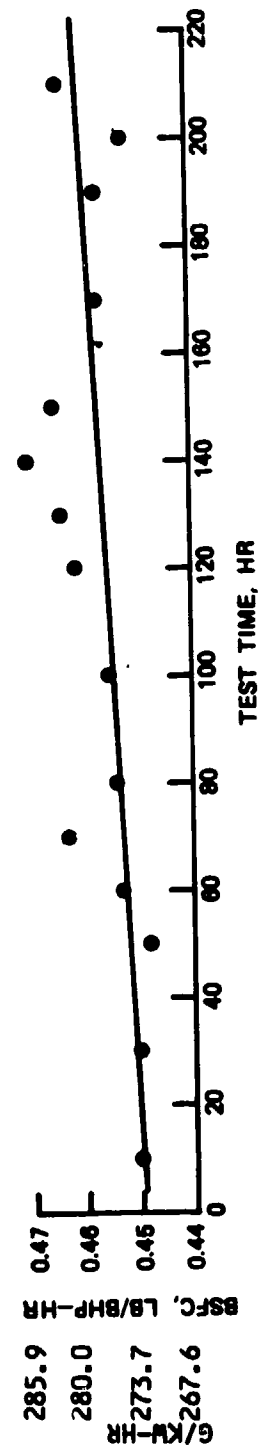
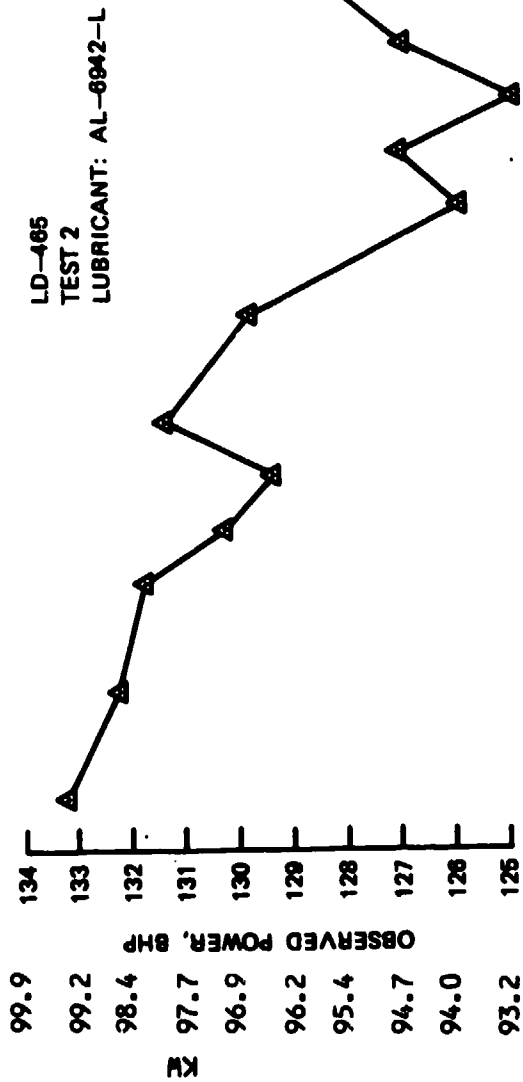
**U.S. Army Fuels & Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284**

LD 465
 TEST 2
 LUBRICANT: AL-6942-L

SUMMARY OF OPERATING DATA

	<u>Power Mode</u>			<u>Idle Mode</u>
	<u>Min.</u>	<u>Avg.</u>	<u>Max.</u>	<u>Avg.</u>
Engine Speed, rpm	2599	2601	2605	762
Engine Torque, ft-lb	252	261	274	13
Fuel Consumption, lb/hr	58.1	59.1	59.8	5.0
BHP (Observed)	124.8	129.1	133.2	1.9
BSFC (Observed)	0.448	0.458	0.470	2.63
<u>Temperatures, °F</u>				
Exhaust Manifold	1220	1270	1320	180
Cooling Water In	170	170	170	95
Cooling Water Out	179	180	180	100
Oil Sump	220	225	226	125
Air In	55	90	110	70
<u>Pressures</u>				
Fuel Transfer Pump, psi	72	73	73	38
Oil Gallery, psi	57	60	63	60
Intake Vacuum, in. H ₂ O	3.7	3.8	4.0	0.4
Exhaust Pressure, in. Hg	1.1	1.5	2.7	0





LD 465
TEST 2
BUILD UP ENGINE MEASUREMENTS

	INCHES			
	MIN	MAX	AVE	SPECIFIED LIMITS
<u>Cylinder Liners (Installed)</u>				
Inside Diameter	4.5523	4.5647	4.5635	4.5630-4.5645
Out of Round	.0005	.0020	.0010	.0015 Max
Piston Skirt Diameter	4.5555	4.5557	4.5557	4.5570-4.5580
<u>#1 Ring</u>				
End Gap	.024	.025	.024	.025 ~ .025
<u>#2 Ring</u>				
End Gap	.024	.030	.025	.025 ~ .035
<u>#3 Ring</u>				
End Gap	.020	.021	.020	.025 ~ .035
Side Clearance	.003	.004	.003	.0025 ~ .0045
<u>#4 Ring</u>				
End Gap	.018	.020	.020	.013 ~ .028
Side Clearance	.001	.002	.002	.0010 ~ .0035

LD465

TEST: 2

LUBRICANT: AL-6942-L

OIL CONSUMPTION, LB

<u>Test Time, Hr.</u>	<u>Oil Consumed</u>	<u>Total Oil Consumed</u>
14	4.48	4.48
28	6.92	11.40
42	4.94	16.34
56	3.10	19.44
70	4.52	23.96
84	0.00	23.96
98	0.56	24.52
112	2.01	26.53
126	0.71	27.24
140	2.19	29.43
154	3.95	33.38
168	3.14	36.52
182	2.30	38.82
196	3.18	42.00

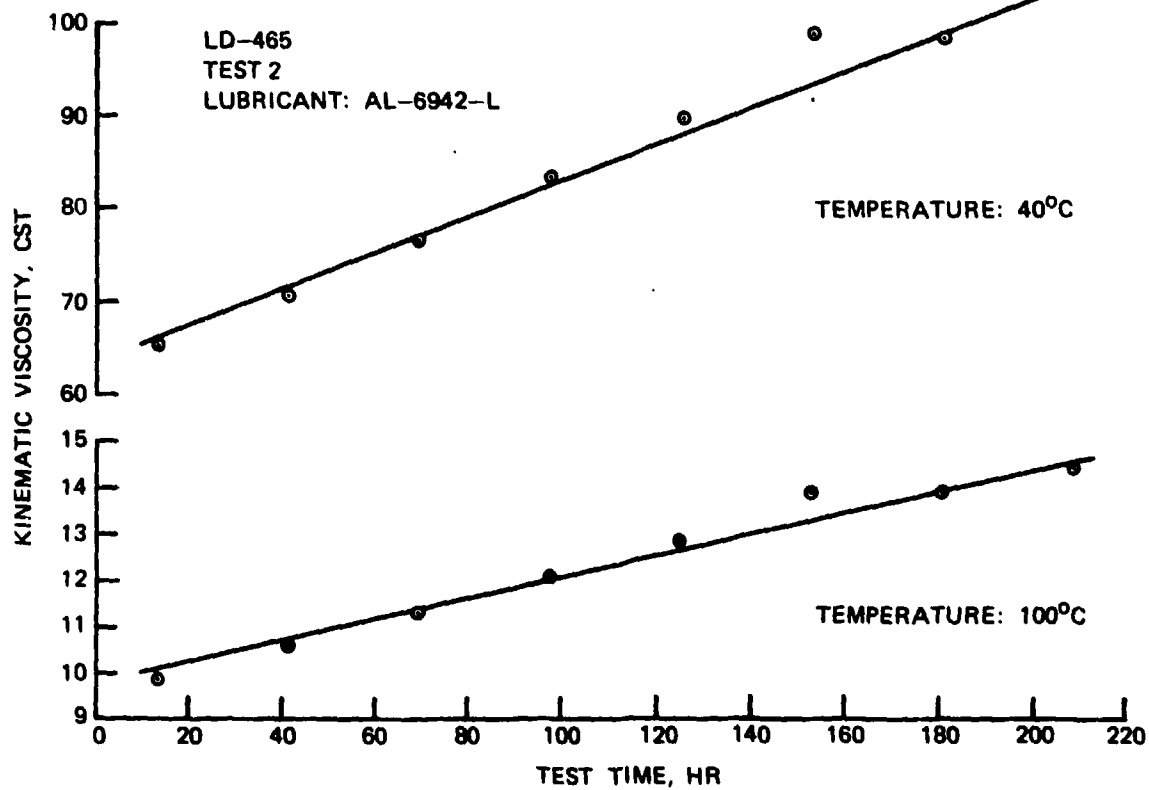
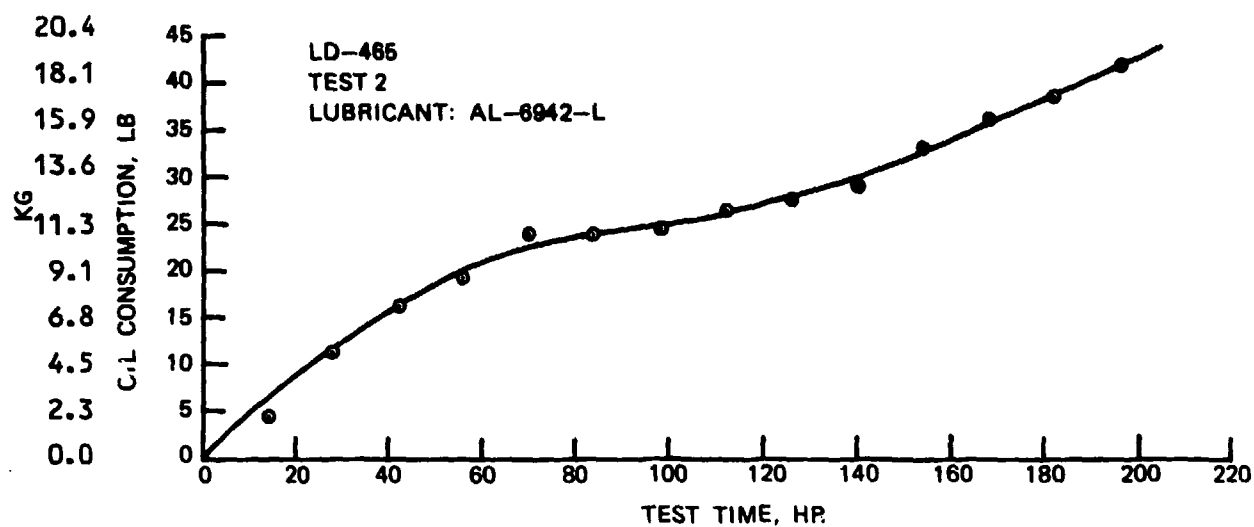
LD 465
TEST 2
LUBRICANT: AL-6942-L

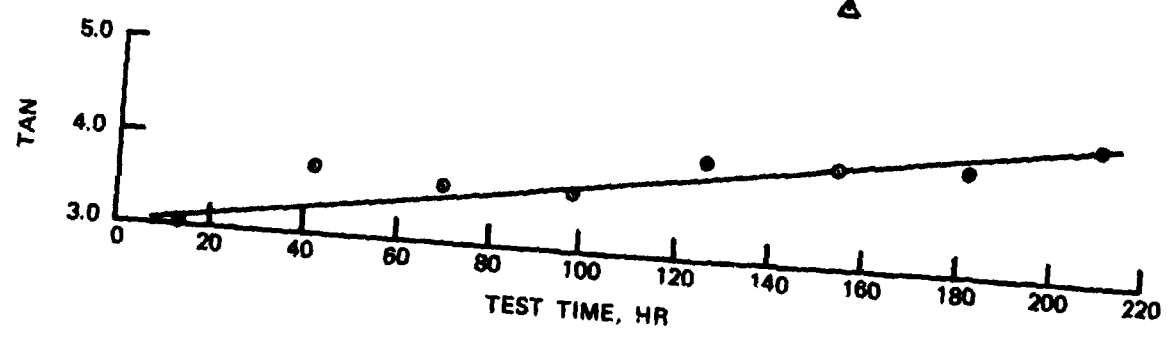
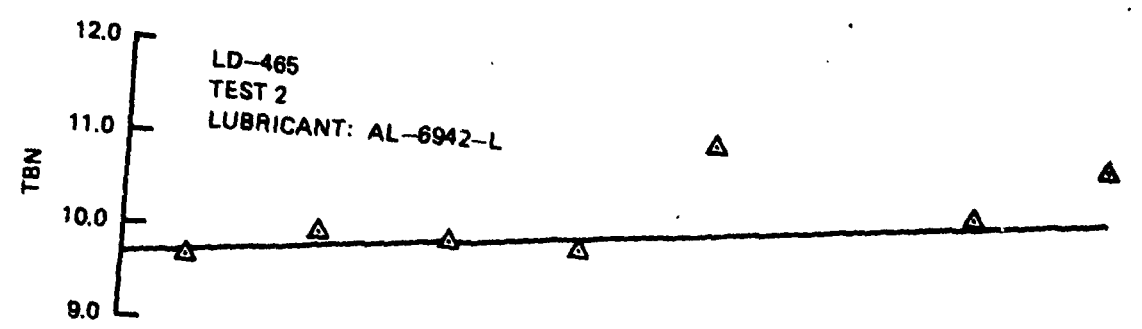
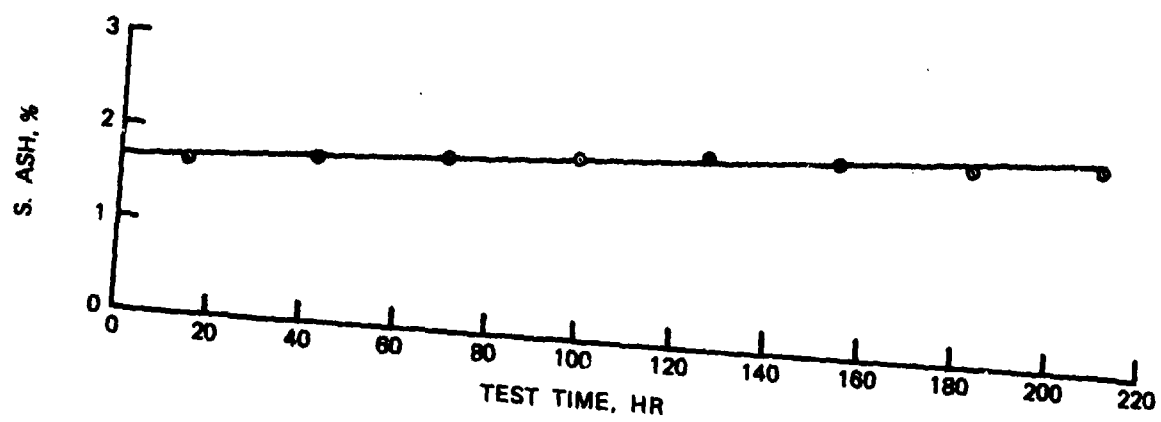
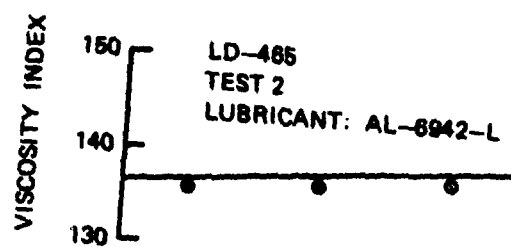
LUBRICANT ANALYSIS

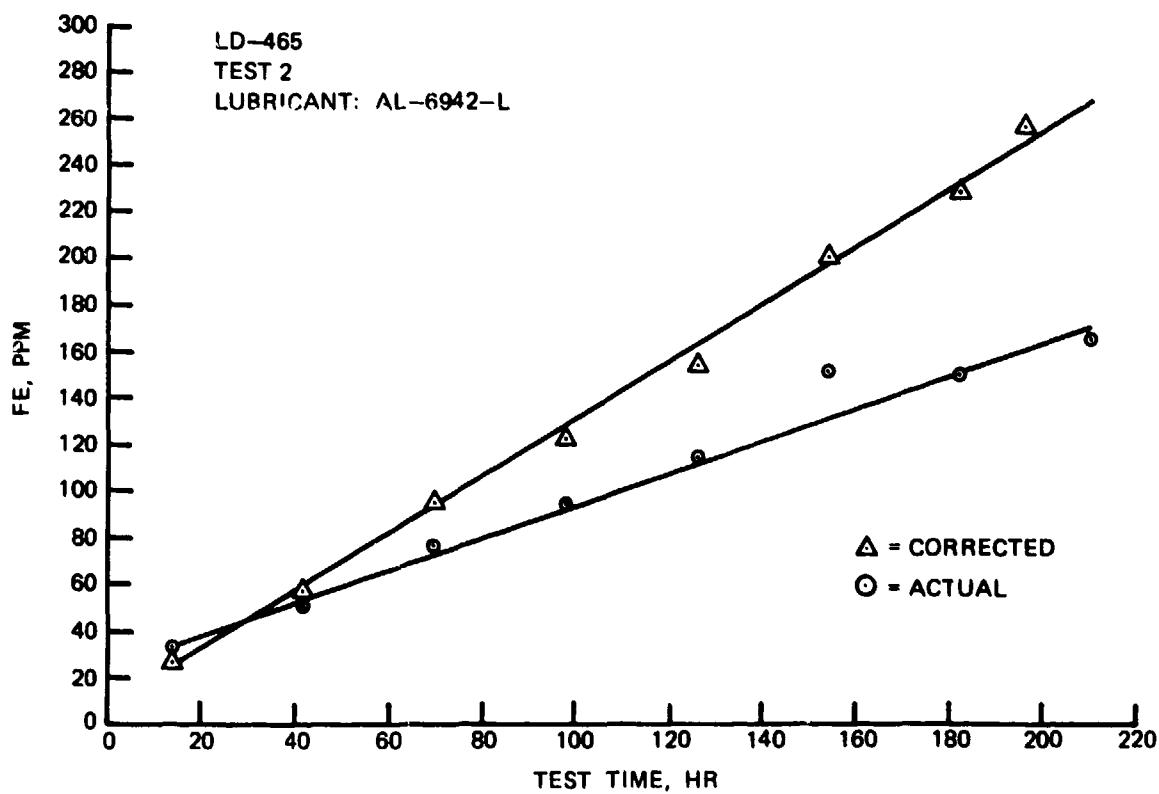
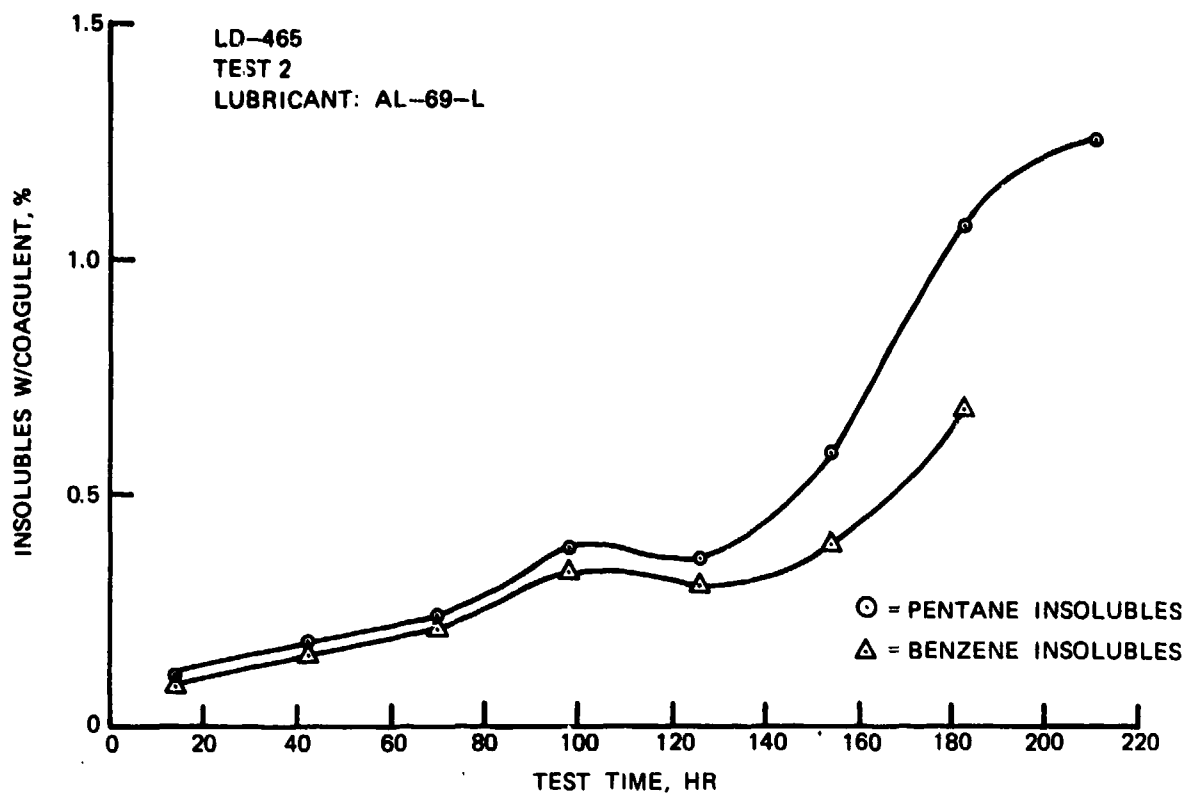
TEST TIME (Hrs.)

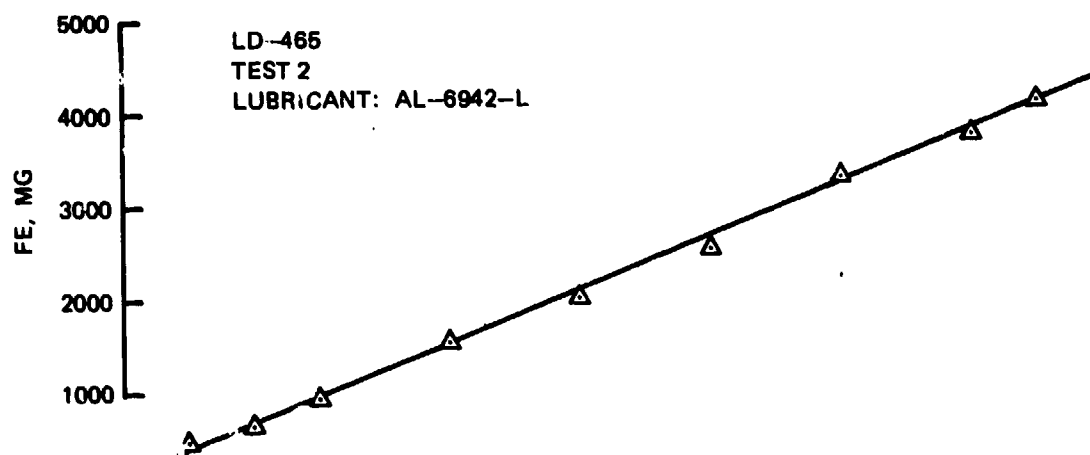
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D-445	64.5	65.4	70.7	76.6	83.5	89.9	99.0	98.6	103.7
D-445	10.2	9.87	10.58	11.30	12.09	12.90	13.95	13.96	14.47
D-2270-74	133	136	137	138	139	142	143	144	143
D-664	3.74	3.03	3.73	3.62	3.65	4.08	4.60	4.15	4.46
D-2896	10.15	9.74	10.05	10.05	10.05	11.27	8.83	10.66	11.27
D-874	1.46	1.66	1.77	1.85	1.96	2.06	2.10	2.12	2.20
D-893	.09	0.11	0.18	0.23	0.39	0.36	0.59	1.07	1.25
D-893	.02	0.09	0.15	0.21	0.33	0.30	0.39	0.68	1.67
	N.D.	30	50	77	95	116	153	151	167

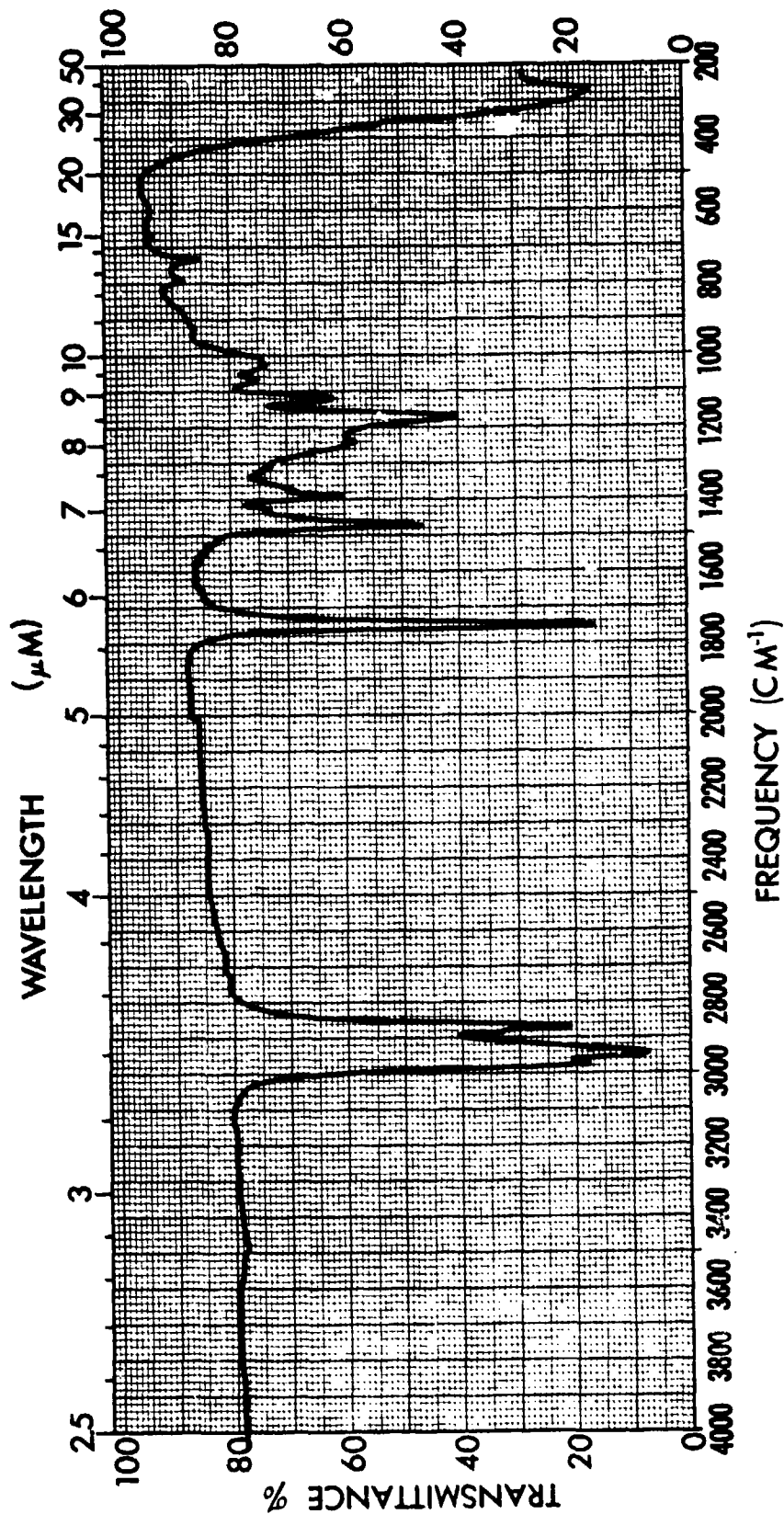
IR Trace No.
K. Vis. Cs @ 40°C
K. Vis. Cs @ 100°C
V.I.
TAN
TBN
S. Ash, %
Pentane Insol. w/coag, %
Benzene Insol. w/coag, %
Fe, ppm by XRF



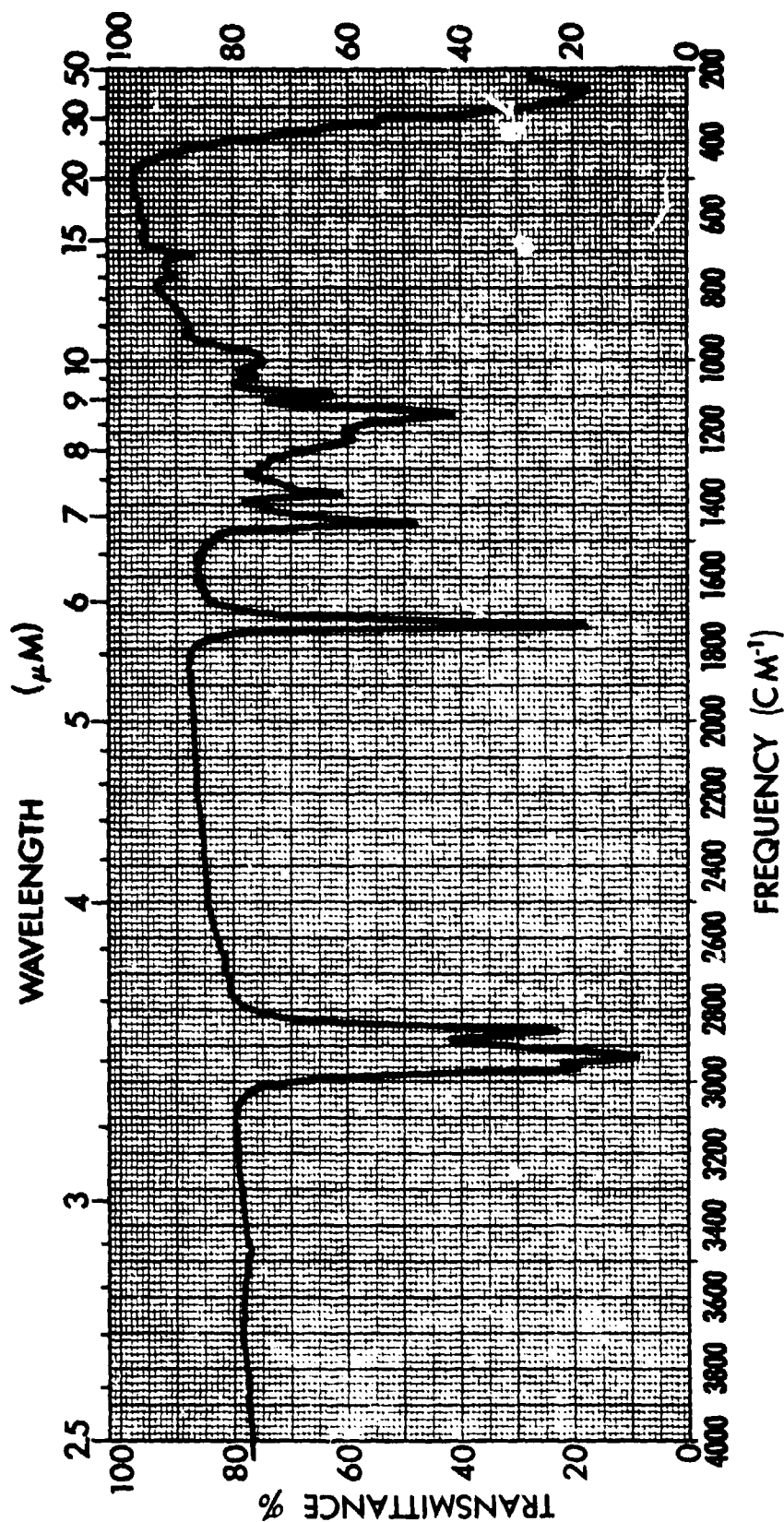




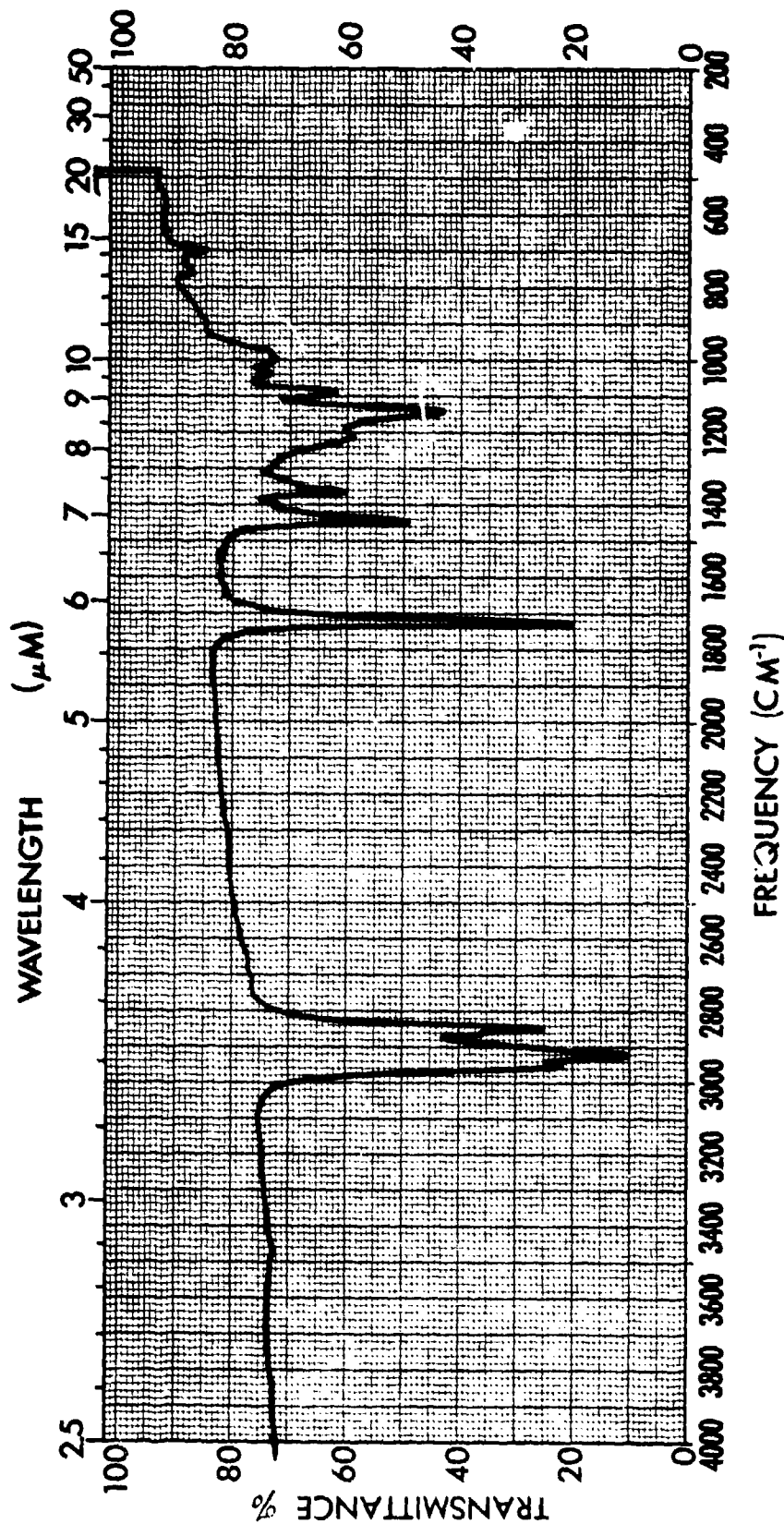




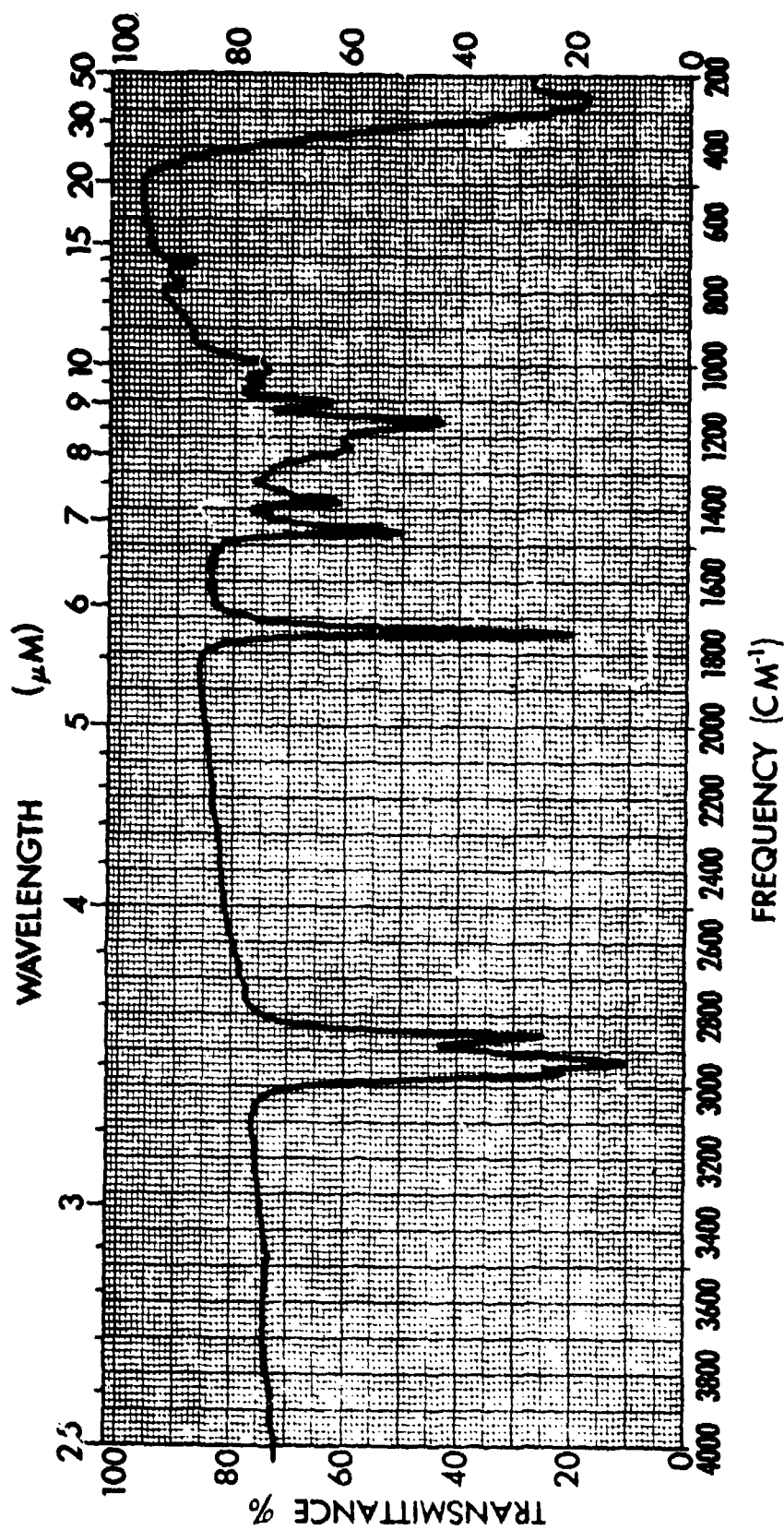
SPECTRUM NO. <u>1624</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6942-L</u>	_____	1. _____	_____
<u>14 HR</u>	PURITY _____	2. _____	_____
<u>TEST 2</u>	PHASE _____	DATE <u>2/7/79</u>	_____
_____	THICKNESS <u>none</u>	OPERATOR <u>DDD</u>	_____



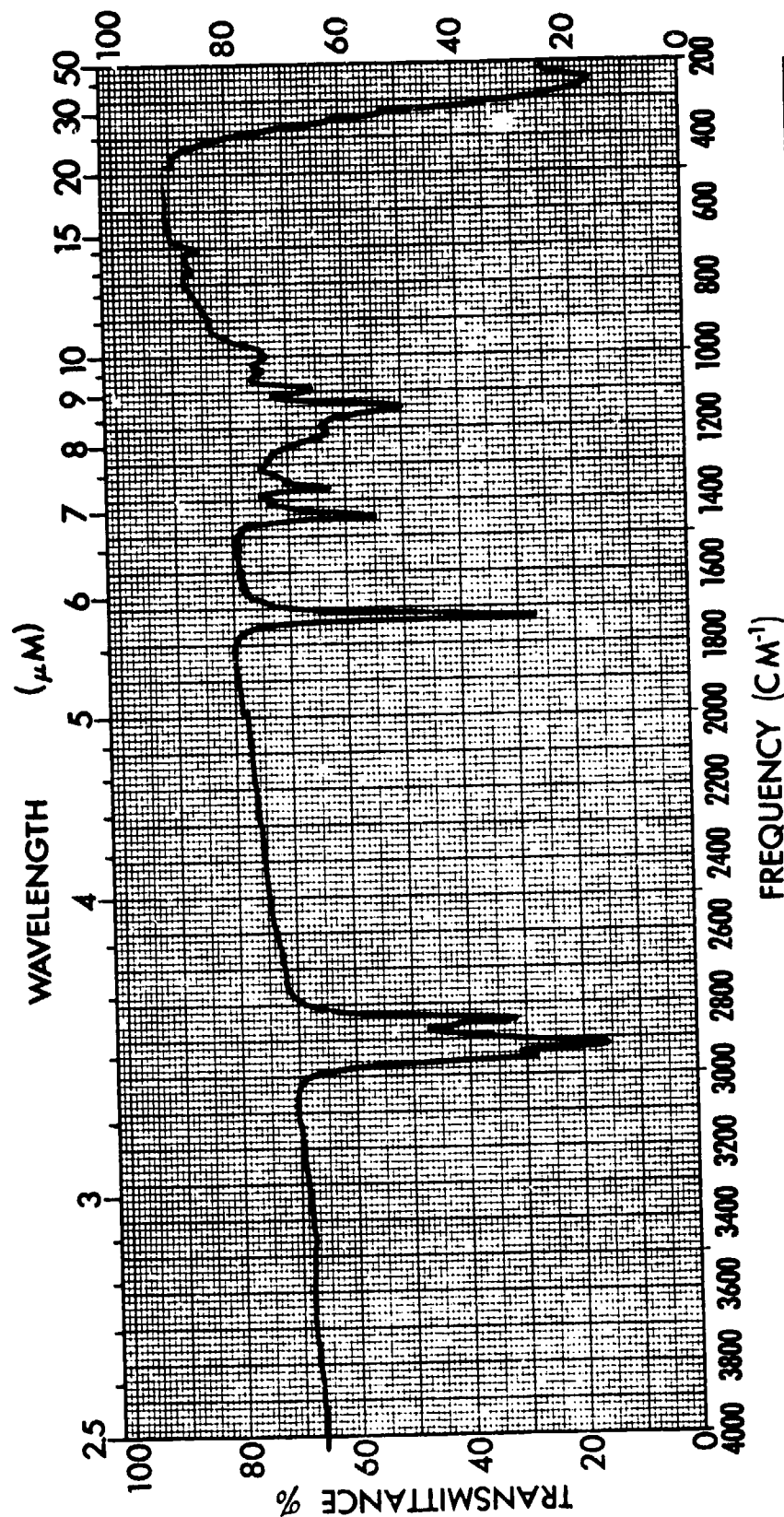
SPECTRUM NO. <u>1625</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6942-L</u>		1. _____	
<u>42 HR</u>	PURITY _____	2. _____	
<u>TEST 2</u>	PHASE _____	DATE <u>2/7/79</u>	
	THICKNESS <u>NONE</u>	OPERATOR <u>DDD</u>	



SPECTRUM NO. 1626	ORIGIN	LEGEND	REMARKS
SAMPLE AL-6942-L		1.	
72 HR	PURITY	2.	
TEST 2	PHASE	DATE 2/7/79	
	THICKNESS NONE	OPERATOR DDD	

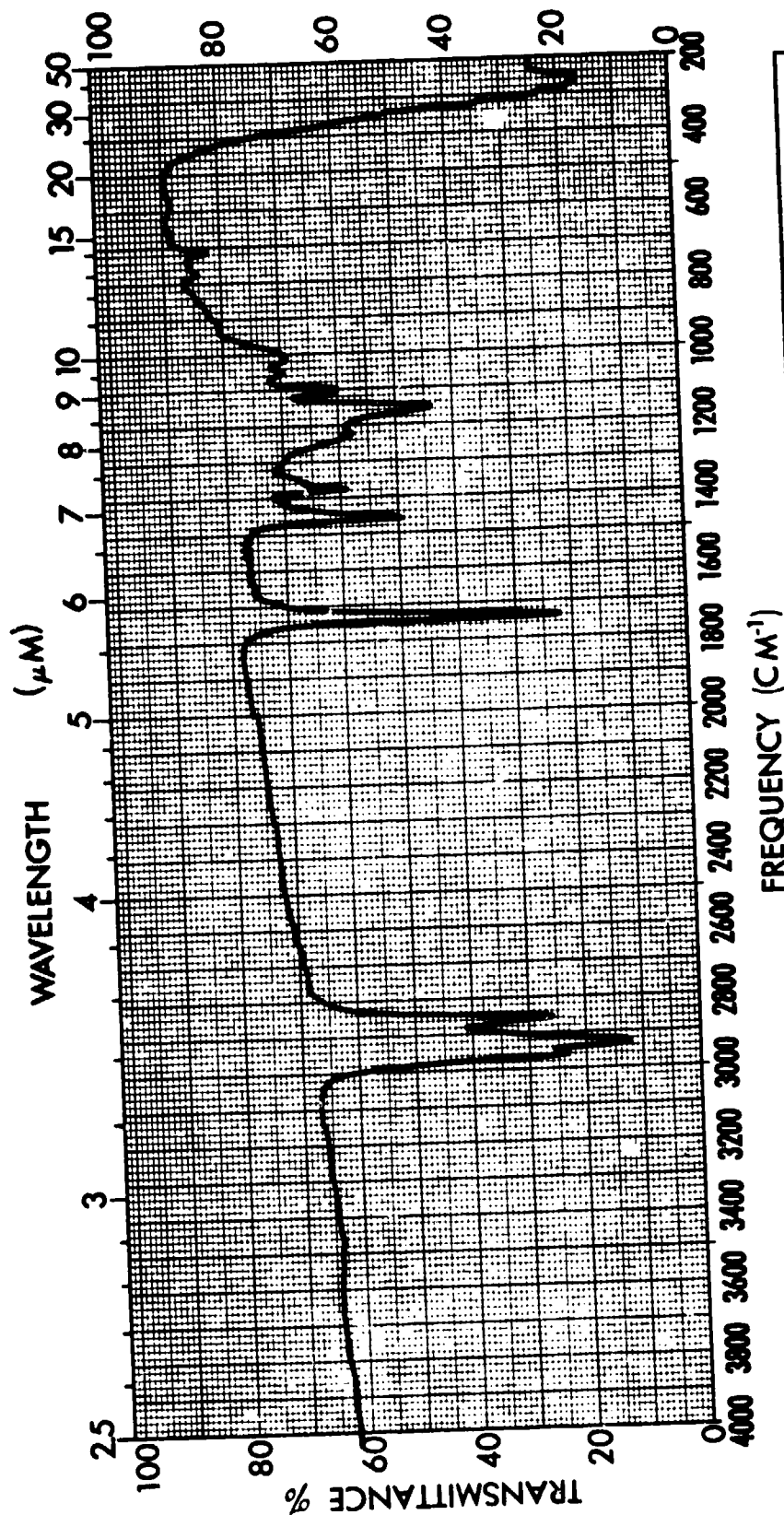


SPECTRUM NO. 1627	ORIGIN	LEGEND	REMARKS
SAMPLE AL-6942-L		1.	
98 HR	PURITY	2.	
TEST 2	PHASE	DATE 2/7/79	
	THICKNESS NONE	OPERATOR DDD	

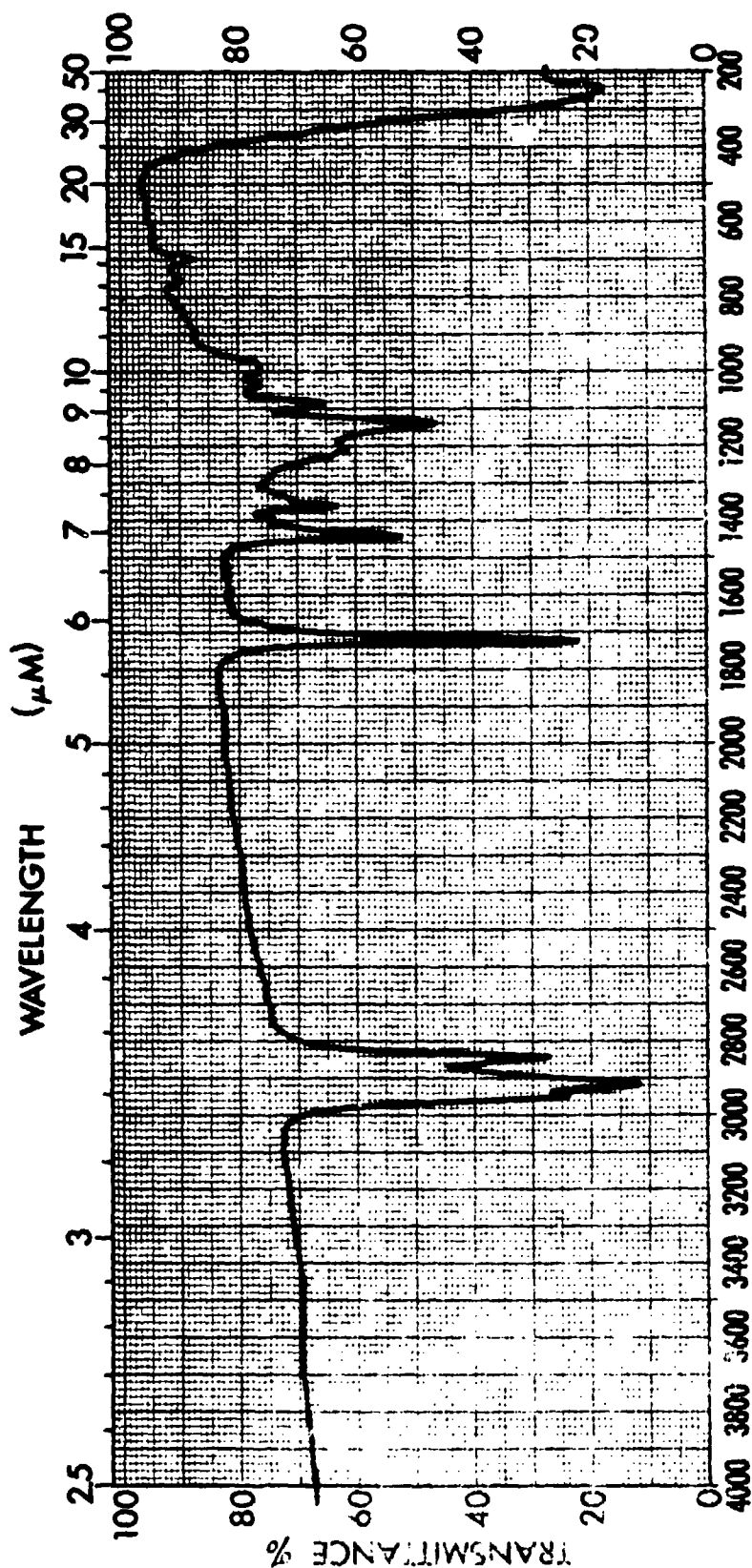


FREQUENCY (CM⁻¹)

SPECTRUM NO. <u>1628</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6942-L</u>	_____	1. _____	_____
<u>126 HR</u>	PURITY _____	2. _____	_____
<u>TEST 2</u>	PHASE _____	DATE <u>2/7/79</u>	_____
_____	THICKNESS <u>NONE</u>	OPERATOR <u>DDD</u>	_____

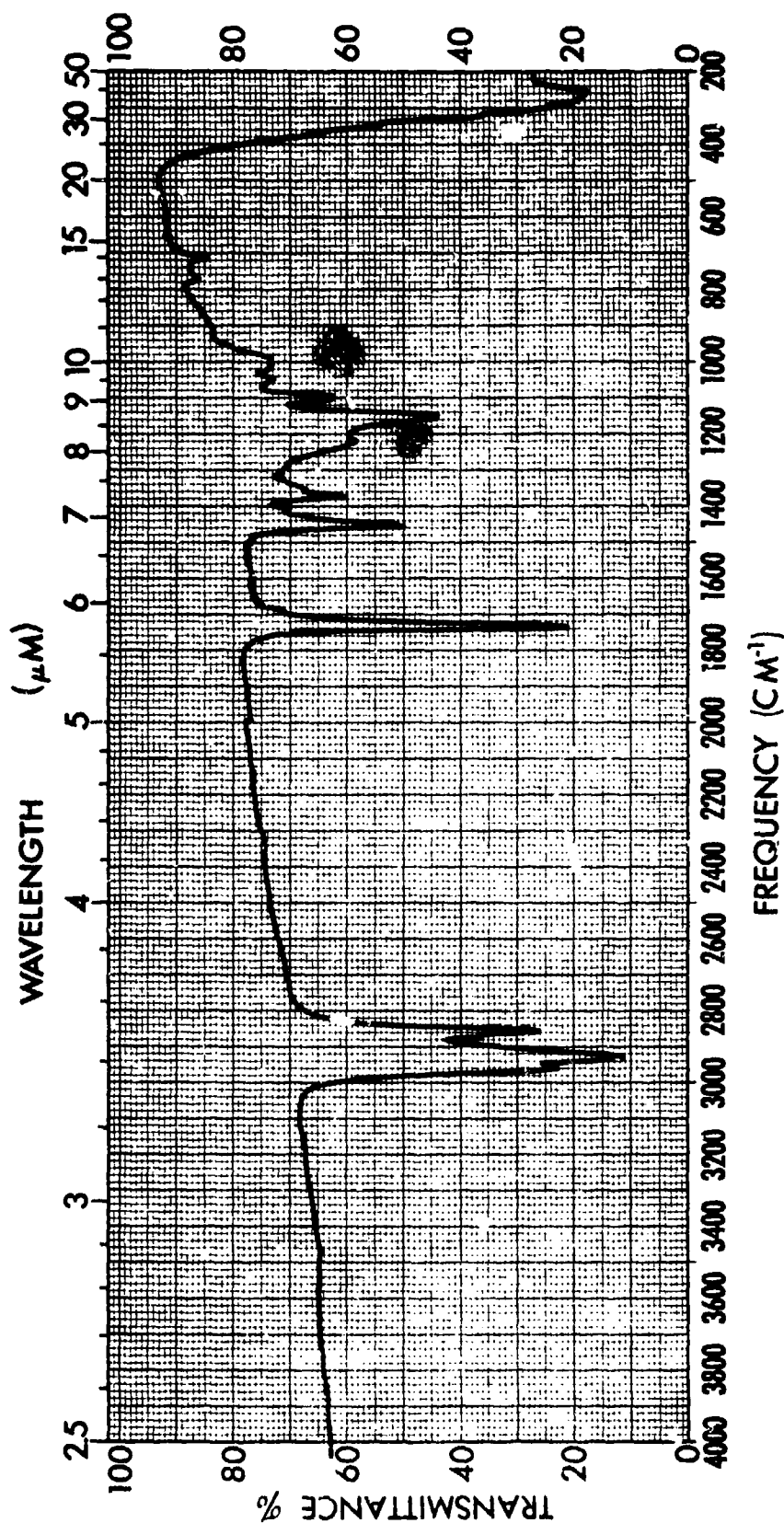


SPECTRUM NO. <u>1629</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6942-L</u>	1. _____	2. _____	
<u>154 HR</u>	PURITY _____	DATE <u>2/7/79</u>	
<u>TEST 2</u>	PHASE _____	OPERATOR <u>DDD</u>	
	THICKNESS <u>NONE</u>		



FREQUENCY (CM⁻¹)

SPECTRUM NO. <u>1630</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6942-L</u>	1. _____	2. _____	
<u>182 HR</u>	PURITY _____	DATE <u>2/7/79</u>	
<u>TEST 2</u>	PHASE _____	OPERATOR <u>DDD</u>	
	THICKNESS <u>NONE</u>		



I-21

SPECTRUM NO. <u>1631</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-6942-L</u>	_____	1. _____	_____
<u>210 HR</u>	PURITY _____	2. _____	_____
<u>TEST 2</u>	PHASE _____	DATE <u>2/7/79</u>	_____
_____	THICKNESS <u>NONE</u>	OPERATOR <u>DDD</u>	_____

TEST: 2
LUBRICANT: AL-6942-L

WEAR MEASUREMENTS

CYLINDER LINER BORE DIAMETER (INCHES)

	Longitudinal			Transverse		
	Before	After	Change	Before	After	Change
1) Top	4.5638	4.5639	0.0001	4.5630	4.5630	0.0000
Center	4.5632	4.5633	0.0001	4.5637	4.5638	0.0001
Bottom	4.5628	4.5629	0.0001	4.5642	4.5642	0.0000
2) Top	4.5633	4.5634	0.0001	4.5640	4.5643	0.0003
Center	4.5636	4.5633	-0.0003	4.5645	4.4647	0.0002
Bottom	4.5636	4.5633	-0.0003	4.5646	4.5649	0.0003
3) Top	4.5634	4.5633	-0.0001	4.5647	4.5650	0.0003
Center	4.5632	4.5630	-0.0001	4.5645	4.5647	0.0002
Bottom	4.5630	4.5630	0.0000	4.5645	4.5646	0.0001
4) Top	4.5625	4.5630	0.0005	4.5629	4.5630	0.0001
Center	4.5626	4.5627	0.0001	4.5632	4.5633	0.0001
Bottom	4.5626	4.5627	0.0001	4.5632	4.5634	0.0002
5) Top	4.5630	4.5639	0.0009	4.5650	4.5649	-0.0001
Center	4.5629	4.5631	0.0002	4.5642	4.5642	0.0000
Bottom	4.5634	4.5636	0.0002	4.5642	4.5641	-0.0001
6) Top	4.5623	4.5629	0.0006	4.5636	4.5637	0.0001
Center	4.5629	4.5630	0.0001	4.5638	4.5637	-0.0001
Bottom	4.5631	4.5632	0.0001	4.5637	4.5636	-0.0001

LD465

TEST: 2

LUBRICANT: AL-6942-L

WEAR MEASUREMENTS

PISTON RING END GAP (INCHES)

Ring Number*	PISTON NUMBER					
	1	2	3	4	5	6
1) Before Test	0.024	0.024	0.024	0.025	0.024	0.025
After Test	0.025	0.026	0.025	0.026	0.027	0.028
Change	0.001	0.002	0.001	0.001	0.003	0.003
2) Before Test	0.030	0.025	0.024	0.025	0.025	0.025
After Test	0.031	0.027	0.024	0.026	0.028	0.027
Change	0.001	0.002	0.000	0.001	0.003	0.002
3) Before Test	0.020	0.021	0.020	0.020	0.020	0.020
After Test	0.022	0.021	0.022	0.020	0.021	0.022
Change	0.002	0.000	0.002	0.000	0.001	0.002
4) Before Test	0.020	0.020	0.020	0.020	0.018	0.020
After Test	0.026	0.025	0.024	0.026	0.025	0.025
Change	0.006	0.005	0.004	0.006	0.007	0.005

* From Top of Piston

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE WheelEd
 TEST HOURS 210
 TEST LABORATORY APRL
 LUBRICANT AL-6942-L

RATER Lyons DATE 1-30-79
 LABORATORY TEST NUMBER 2
 STAND NO. 6 ENGINE NO. 3904343
 FUEL AL-7799-F

PISTON NO. 1

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC 1.00	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT		
	MHC 0.75														
	MC 0.50	10 5.00				80 40.00									
	LC 0.25	70 17.50					15 3.75								
	VLC 0.15														
LACQUER	CARBON RATING	22.50				40.00	3.75								
	BL 0.100					20 2.00									
	DBrL 0.075	20 1.50													
	AL 0.050		100 5.00	100 5.00	100 5.00		85 4.25			100 2.50	100 2.50			100 5.00	
	LAL 0.025														
ZONAL RATING	VLAL 0.010														
	RL 0.001														
	LACQUER RATING	1.50	5.00	5.00	5.00	2.00	4.25	2.50	2.50					5.00	
	CLEAN 0														
	ZONAL RATING														
LOCATION FACTOR															
WEIGHTED RATING		24.00	5.00	5.00	5.00	42.00	8.00	2.50	2.50					5.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFLRL
 LUBRICANT AL-6942-L

RATER Lyons DATE 1-30-79
 LABORATORY TEST NUMBER 2
 STAND NO. 6 ENGINE NO. 3904343
 FUEL AL-7790 - F

PISTON NO. 2

		GROOVES										LANDS				NO. 1 GROOVE, VOLUME %
DEPOSIT TYPE	DEPOSIT FACTOR	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING		UNDER-CROWN
		AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	
CARBON	HC 1.00	10	10.00													
	MHC 0.75															
	MC 0.50	10	2.50							80	20.00					
	LC 0.25									20	5.00					
	VLC 0.15															
CARBON RATING		12.50								25.00						
LACQUER	BL 0.100															
	DBL 0.075	85	6.375									5	5.50			
	AL 0.050															
	LAL 0.025											95	4.75			
	VLAL 0.010															
	RL 0.001															
LACQUER RATING		6.375	5.00	5.00	5.00							5.25	2.50	2.50	2.50	5.00
CLEAN	0															
ZONAL RATING																
LOCATION FACTOR																
WEIGHTED RATING		18.875	5.00	5.00	5.00					25.00	5.25	2.50	2.50	2.50	2.50	5.00

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 3

TEST PROCEDURE Wheel
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-6942-L

RATER Lyons DATE 1-30-79
 LABORATORY TEST NUMBER 2
 STAND NO. 6 ENGINE NO. 3904343
 FUEL AL-7799-F

TEST LABORATORY <u>AEPL</u>										STAND NO. <u>6</u> ENGINE NO. <u>3504 343</u>										NO. 1 GROOVE, VOLUME-%		UNDER-CROWN																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
LUBRICANT <u>AL-6942-L</u>										FUEL <u>AL-7799-F</u>										PISTON WTD* RATING				84.50																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4		NO. 3		NO. 2		NO. 1		NO. 4	

•WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Wheelled
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-6942-L

RATER Lyons DATE 1-30-79
 LABORATORY TEST NUMBER 2
 STAND NO. 6 ENGINE NO. 3904343
 FUEL AL-7799-F

PISTON NO. 4

NO. 1 GROOVE, VOLUME-%	93.875
PISTON WTD* RATING	

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN		
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4				
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT		AREA-%	DEMERIT
CARBON		HC	1.00																	
	MHC	0.75	25	18.75																
	MC	0.50																		
	LC	0.25	10	2.50																
	VLC	0.15																		
	CARBON RATING		21.25																	
LACQUER		BL	0.100																	
	DBrL	0.075	65	4.875																
	AL	0.050			100	5.00	100	5.00	100	5.00										
	LAL	0.025																		
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		4.875		5.00		5.00		5.00											
	CLEAN	0																		
	ZONAL RATING																			
	LOCATION FACTOR																			
	WEIGHTED RATING		26.125		5.00		5.00		5.00											

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AL-6942-L
 LUBRICANT AL-6942-L

RATER Lyons DATE 1-30-79
 LABORATORY TEST NUMBER 2
 STAND NO. 6 ENGINE NO. 3904343
 FUEL AL-7799-F

PISTON NO. 5

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				PISTON WTD* RATING		UNDER-CROWN	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	AREA-%	DEMERIT		
CARBON	HC 1.00												
	MHC 0.75												
	MC 0.50	20	10.00			90	45.00						
	LC 0.25	10	2.50										
	VLC 0.15												
CARBON RATING		12.50				45.00							
LACQUER	BL 0.100	70	7.00					5	5.00				
	DBrL 0.075							5	.375				
	AL 0.050		100	5.00	100	5.00		90	4.50			100	5.00
	LAL 0.025									100	2.50	100	2.50
	VLAL 0.010						10	.10					
LACQUER RATING		7.00	5.00	5.00	5.00	.10		5.375		2.50	2.50	5.00	
CLEAN	0												
ZONAL RATING													
LOCATION FACTOR													
WEIGHTED RATING		19.50	5.00	5.00	5.00	45.10		5.375		2.50	2.50	5.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

RATER Lyons DATE 1-30-79 PISTON NO. 6
 LABORATORY TEST NUMBER 2
 STAND NO. 6 ENGINE NO. 3904343
 FUEL AL-7799-F

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-6942-L

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC 1.00										
	MHC 0.75										
	MC 0.50	10	5.00			90	45.00				
	LC 0.25	90	22.50				5				
	VLC 0.15										
LACQUER	CARBON RATING	27.50				45.00					
	BL 0.100										
	DBrL 0.075						5				
	AL 0.050		100	5.00	100	5.00	90	4.50	100	2.50	100
	LAL 0.025				100	2.50					5.00
LACQUER	VLAL 0.010										
	RL 0.001										
	LACQUER RATING		5.00	5.00	2.50	.10	5.00	2.50	2.50	2.50	5.00
	CLEAN 0										
	ZONAL RATING										
LOCATION FACTOR											
WEIGHTED RATING		27.50	5.00	5.00	2.50	45.10	5.00	2.50	2.50	2.50	5.00

*WEIGHTED TOTAL DEPOSITS

RING DEPOSITS TEST 2

Engine Model Continental LD 465 Serial No. 3904343 Date 1-30-79
 Fuel AL-799-F Lubricant AL-6942-L Observer Lyons

Cylinder Number		1		2		3		4		5		6	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Piston Ring	Top	1	0	0	0	0	0	0	0	0	10	0	5
		2	0	10	20	0	10	0	15	0	15	0	25
		3	0	100	100	0	90	0	95	0	95	0	95
		4	0					0				0	
	ID	1	0	100	100	0	100	0	100	0	95	0	60
		2	0	100	100	0	100	0	100	0	100	0	100
		3	0	100	100	0	100	0	100	0	100	0	100
		4											
	Bottom	1	0	0	0	0	0	0	0	0	0	0	0
		2	0	40	50	0	30	0	0	0	75	0	75
		3	0	75	85	0	80	0	0	0	90	0	90
		4											

See pages 4, 36 and 37 of Manual. Areas previously rated for carbon, rate 0 for lacquer

RING FACE CONDITION TEST 2

Engine Model LD 465 Serial No. 3904343 Date 1-30-79
 Fuel AL-7799 -F Lubricant AL-6942-L Observer Lyons

	Cylinder Number					
	1	2	3	4	5	6
First Ring	N	N	N	N	N	N
Second Ring	N	N	N	N	N	N
Third Ring	N	N	N	N	N	N
Fourth Ring	N	N	N	N	N	N
Oil Ring Slots-% Open	100	100	100	100	100	100

Pages 1 and 2 and 59 through 65 of Manual.

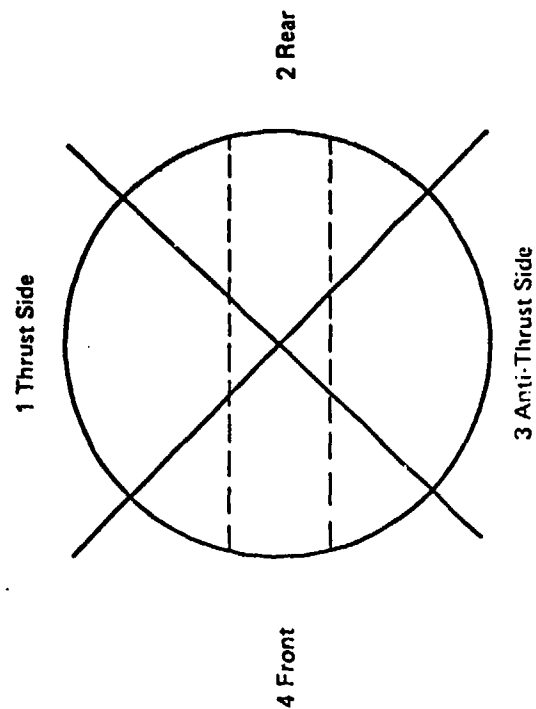
N = NORMAL

PISTON GROOVE INSIDE DIAMETER-% RING SUPPORTING CARBON

TEST 2

Engine Model Continental LD-465 Serial No. 3904343 Date 1-30-78
 Fuel AL-7799-F Lubricant AL-6942-L Observer Lyons

Piston Ring	Quadrant	Piston Number					
		1	2	3	4	5	6
1	1	0	5	0	0	0	0
	2	0	0	0	0	0	0
	3	80	0	0	0	0	0
	4	0	10	0	0	0	0
2	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0



PISTON SURFACE CONDITION

TEST 2

Engine Model Continental LD-465 Serial No. 3904343 Date 1-30-79
 Fuel AL-7799-F Lubricant AL-6942-L Observer Lyons

	Piston Number					
	1	2	3	4	5	6
Top Land	N	N	N	N	N	N
Skirt	N	N	N	N	N	N
Piston Pin	N	N	N	N	N	N

Pages 1 through 2 and 59 through 65 of Manual.
 N = NORMAL

VALVE SURFACE CONDITIONS TEST 2

Engine Model CONTINENTAL LD 465 Serial No. 3904343 Date 1-29-79
 Fuel AL-7799-F Lubricant AL-6942-L Observer Lyons

	Intake						Exhaust					
	1	2	3	4	5	6	1	2	3	4	5	6
Freedom in Guide	F	F	F	F	F	F	F	F	F	F	F	F
Head	N	N	N	N	N	N	N	N	N	N	N	N
Face	N	N	N	N	N	N	N	N	N	N	N	N
Seat	N	N	N	N	N	N	N	N	N	N	N	N
Stem	N	N	N	N	N	N	N	N	N	N	N	N
Tip	N	N	N	N	N	N	N	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

Tulip Deposit 2.8 2.5 3.0 2.3 2.5 3.0 .5 .5 .5 .5 .5 .5

F = FREE

N = NORMAL

CYLINDERS

TEST 2

Engine Model Continental LD-465 Serial No. 3904343 Date 1-30-79
 Fuel AL-4499-F Lubricant AL-6942-L Observer Lyons

Cylinder Number													
		1		2		3		4		5		6	
Deposits	Cylinder Head	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Cylinders	ART	50	50	70	30	70	20	70	30	85	15	75	25
	RTA	0	0	0	0	0	0	0	0	0	0	0	0
	BRT	0	0	0	0	0	0	0	0	0	0	0	0
Surface Condition													
Cylinders	RTA	5% LT Glaze	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches
	BRTA	LT Scratches											

Carbon and Ash: Use Volume Factor Pages 5 and 40 through 47 of Manual.
 Indicate H, M, or S

Lacquer: Use Pages 4, 36 and 37

For Surface Condition—See Pages 1, 2, 16 through 23 and 54 through 65.

SURFACE CONDITION

TEST 2

Engine Model Continental LD 465 Serial No. 3904343 Date 1-30-79
 Fuel AL-7799-F Lubricant AL-6942-L Observer LYons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing	THE	ONE	REMOVED	LOOKS	VERY	GOOD	
--Journal							
Rod-Bearing	NORMAL						
--Journal							
Piston Pin	NORMAL						
Bushing							

Note surface condition. See pages 1, 2, 16 through 22 and 54 through 65 of Manual.

LD-465
TEST 2
AFTER TEST CONDITION OF CYLINDER HEADS



CYLINDERS 3, 2, AND 1

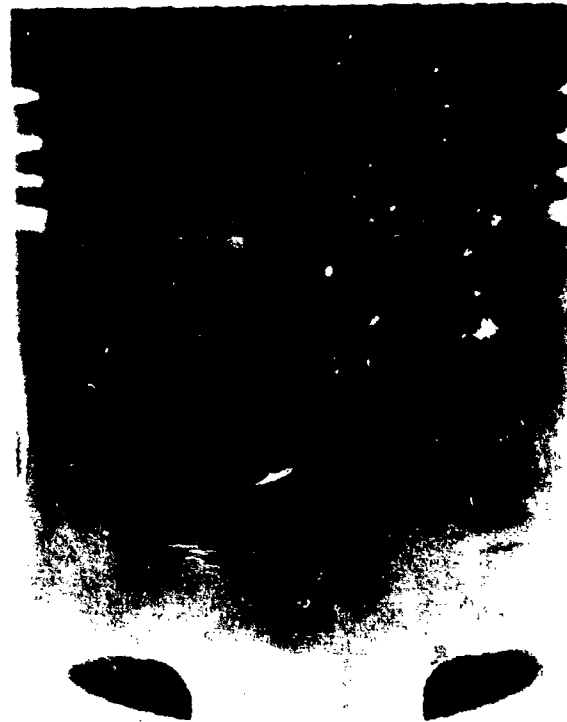


CYLINDERS 6, 5, AND 4

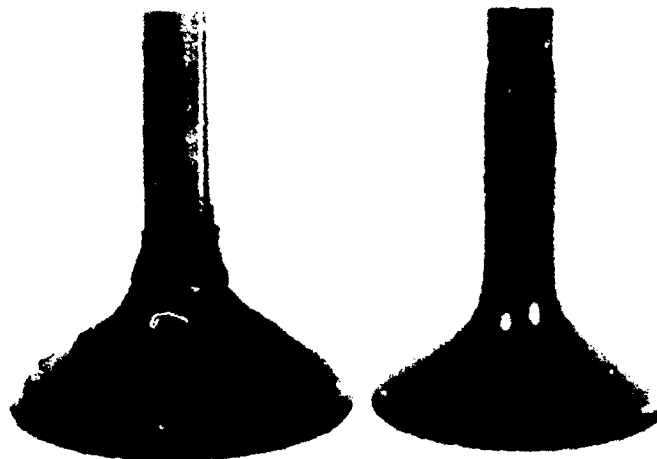
LD-465
TEST 2
AFTER TEST CONDITION OF NO. 1 PISTON AND VALVES



PISTON THRUST SIDE



PISTON ANTI-THRUST SIDE

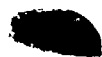
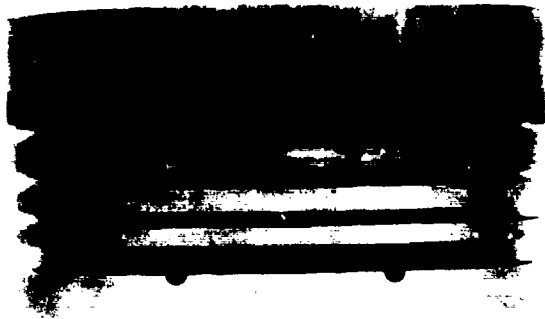


INTAKE AND EXHAUST VALVES

LD-465

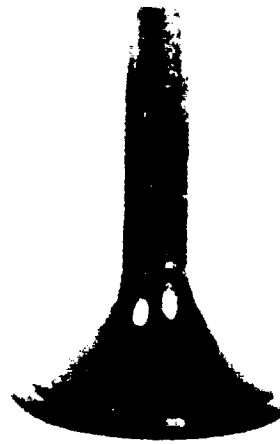
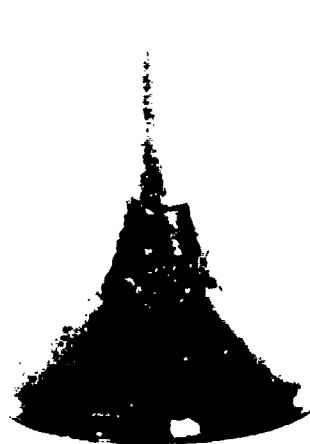
TEST 2

AFTER TEST CONDITION OF NO. 2 PISTON AND VALVES



PISTON THRUST SIDE

PISTON ANTI-THRUST SIDE



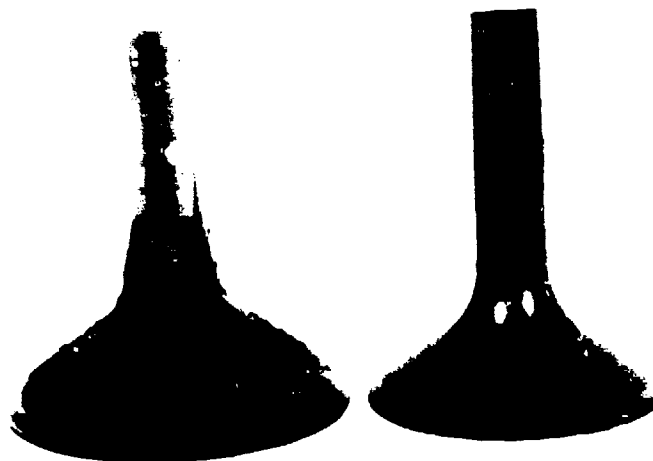
INTAKE AND EXHAUST VALVES

LD-465
TEST 2
AFTER TEST CONDITION OF NO. 3 PISTON AND VALVES



PISTON THRUST SIDE

PISTON ANTI-THRUST SIDE



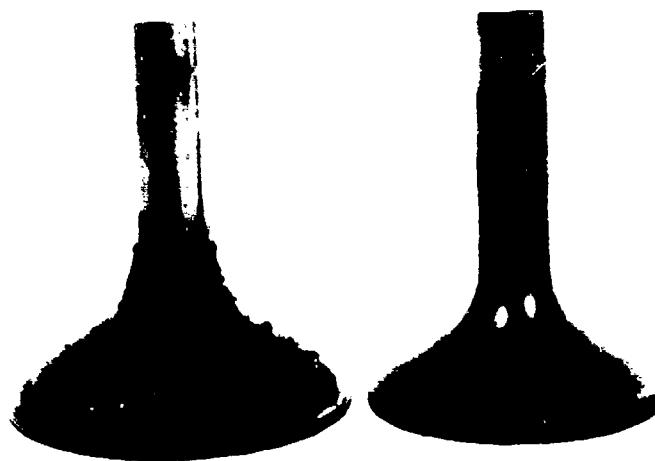
INTAKE AND EXHAUST VALVES

LD-465
TEST 2
AFTER TEST CONDITION OF NO. 4 PISTON AND VALVES



PISTON THRUST SIDE

PISTON ANTI-THRUST SIDE

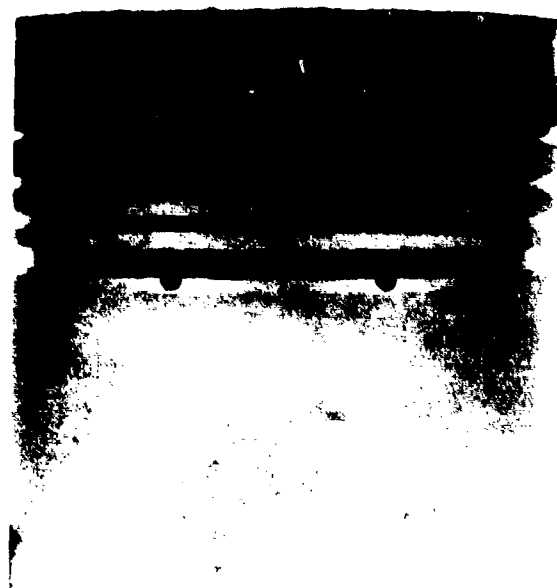


INTAKE AND EXHAUST VALVES

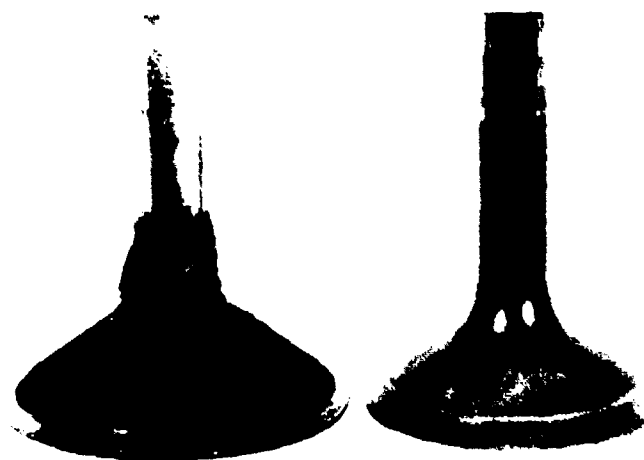
LD-465
TEST 2
AFTER TEST CONDITION OF NO. 5 PISTON AND VALVES



PISTON THRUST SIDE



PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

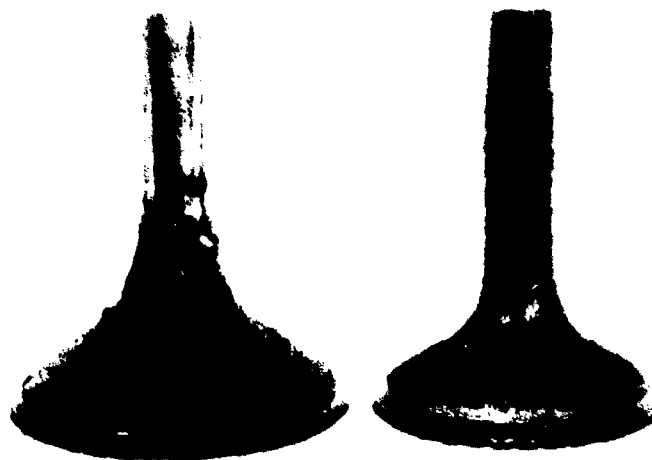
LD-465
TEST 2
AFTER TEST CONDITION OF NO. 6 PISTON AND VALVES



PISTON THRUST SIDE



PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

APPENDIX J

ENGINE-LUBRICANT COMPATIBILITY TEST #3
210-HOUR WHEELED-VEHICLE CYCLE
USING LD 465 DIESEL ENGINE

ENGINE-LUBRICANT COMPATIBILITY TEST
210-HOUR WHEELED-VEHICLE CYCLE
USING LD 465 DIESEL ENGINE

Test Lubricant: AL-7288-L
Test Fuel: AL-8060-F
Engine Test Number: 3
Date Completed: 5 March 1979

Conducted for

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

by

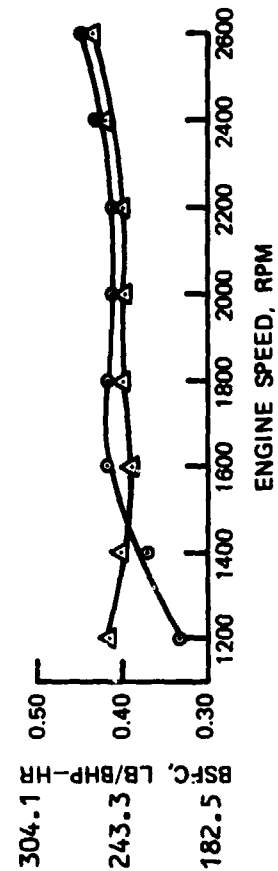
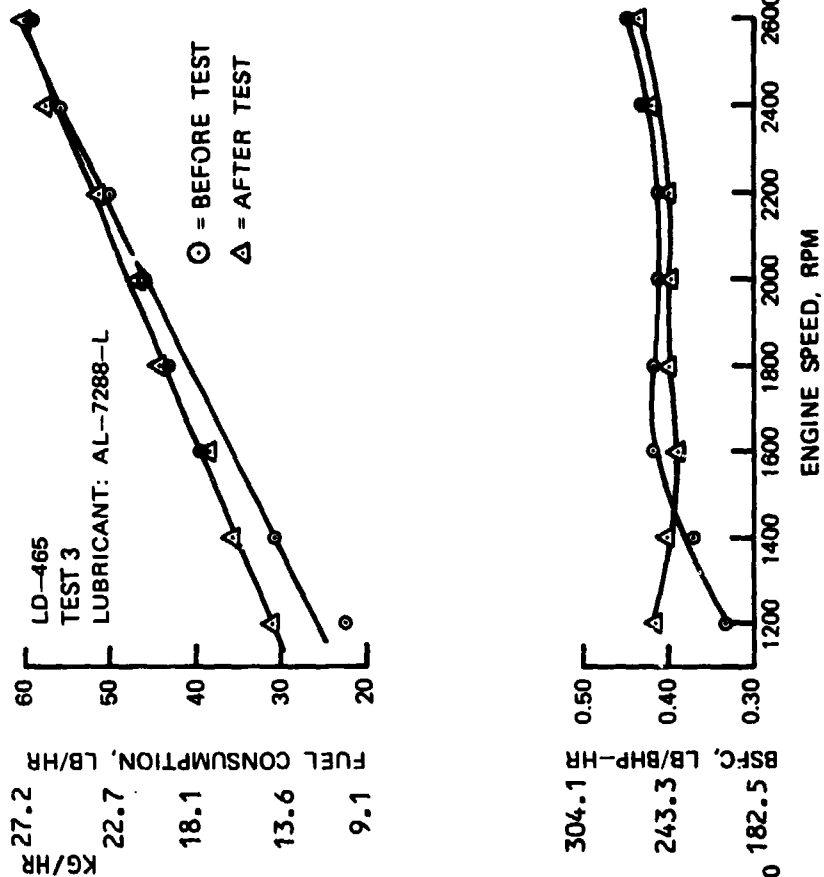
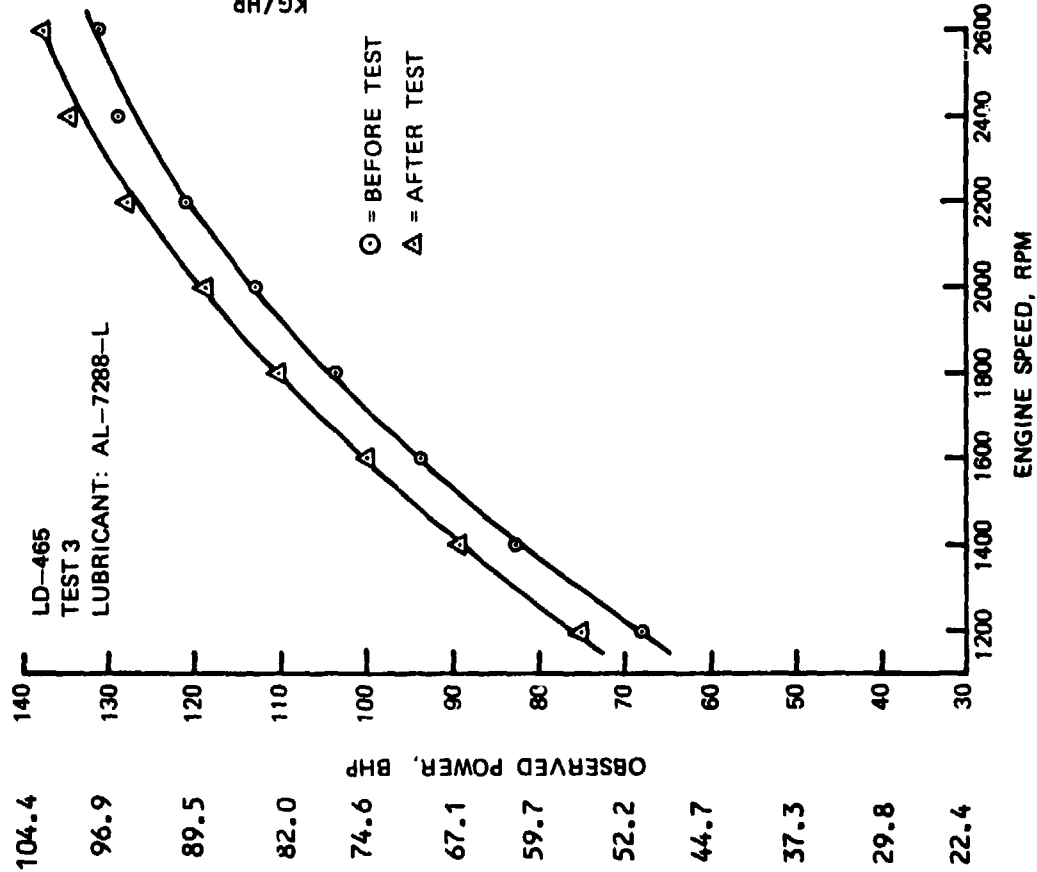
U.S. Army Fuels & Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

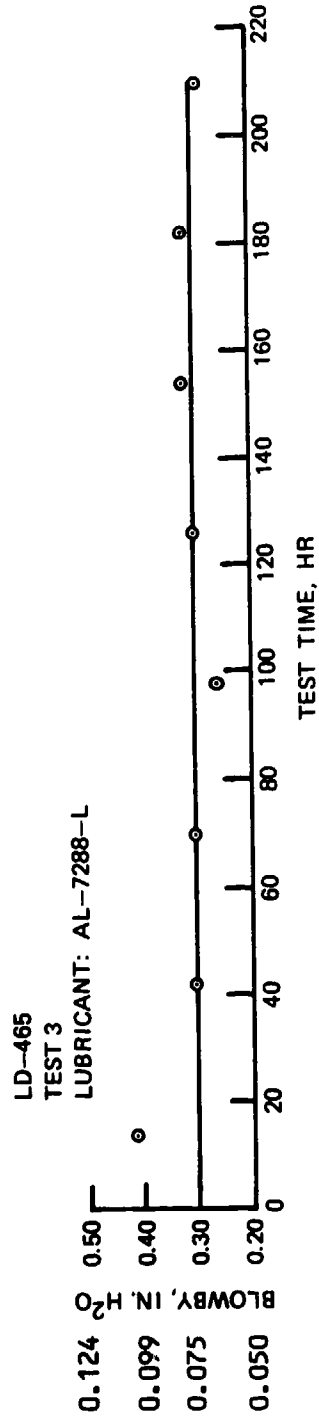
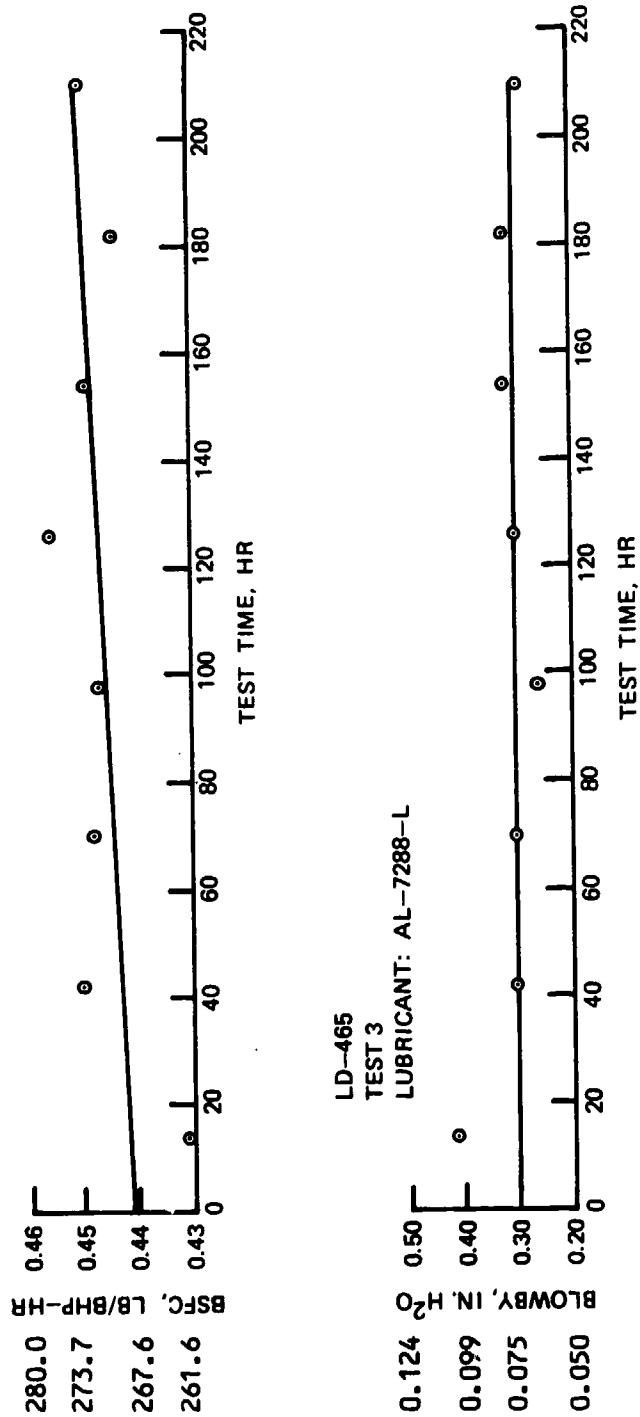
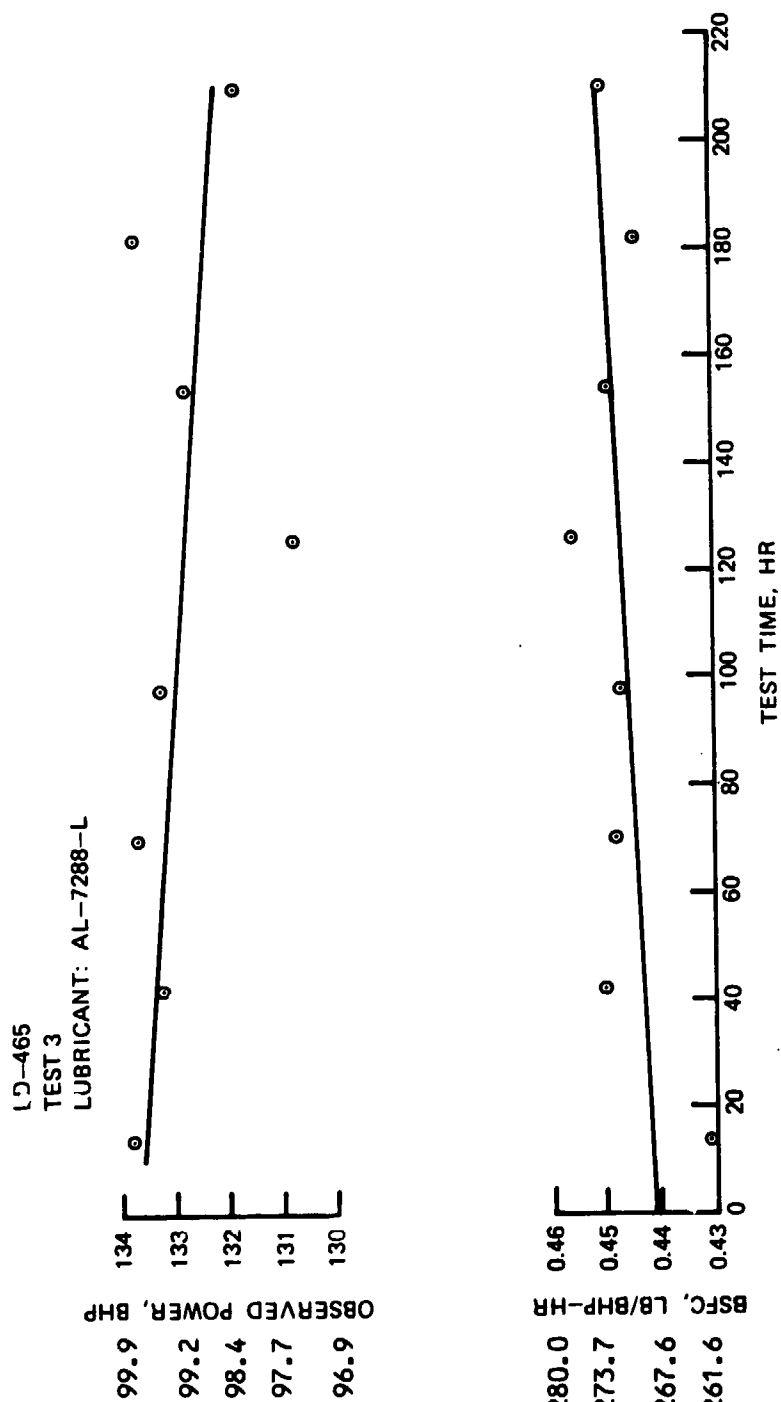
PREPARED BY: [illegible]

LD 465
TEST 3
LUBRICANT: AL-7288-L

SUMMARY OF OPERATING DATA

	Power Mode			Idle Mode
	Min.	Avg.	Max.	Avg.
Engine Speed, rpm	2599	2601	2605	758
Engine Torque, ft-lb	261	267	281	11
Fuel Consumption, lb/hr	57.7	59.6	60.5	4.7
BHP (Observed)	130.8	133.0	133.8	1.6
BSFC (Observed)	0.431	0.450	0.456	2.94
<u>Temperatures, °F</u>				
Exhaust Manifold	1210	1270	1310	170
Cooling Water In	170	170	170	95
Cooling Water Out	180	180	180	100
Oil Sump	222	225	226	125
Air In	64	85	111	75
<u>Pressures</u>				
Fuel Transfer Pump, psi	72	73	73	37
Oil Gallery, psi	57	58	60	53
Intake Vacuum, in. H ₂ O	3.4	3.5	3.6	0.3
Exhaust Pressure, in. Hg	1.4	1.7	2.1	0





LD 465
TEST 3
BUILD UP ENGINE MEASUREMENTS

<u>CYLINDER LINERS (INSTALLED)</u>	<u>INCHES</u>			<u>SPECIFIED LIMITS</u>
	<u>MIN</u>	<u>MAX</u>	<u>AVE</u>	
Inside Diameter	4.5625	4.5644	4.5635	4.5630~4.5645
Out of Round	.0000	.0016	.0006	.0015 MAX
Piston Skirt Diameter	4.5555	4.5558	4.5556	4.5570~4.5580
<u># 1 Ring</u>				
End Gap	.020	.025	.024	.025~.035
<u># 2 Ring</u>				
End Gap	.021	.024	.023	.025~.035
<u># 3 Ring</u>				
End Gap	.019	.024	.021	.025~.035
Side Clearance	.003	.003	.003	.0025~.0045
<u># 4 Ring</u>				
End Gap	.016	.023	.020	.013~.028
Side Clearance	.0015	.0015	.0015	.0010~.0035

LD465
TEST: 3
LUBRICANT: AL-7288-L

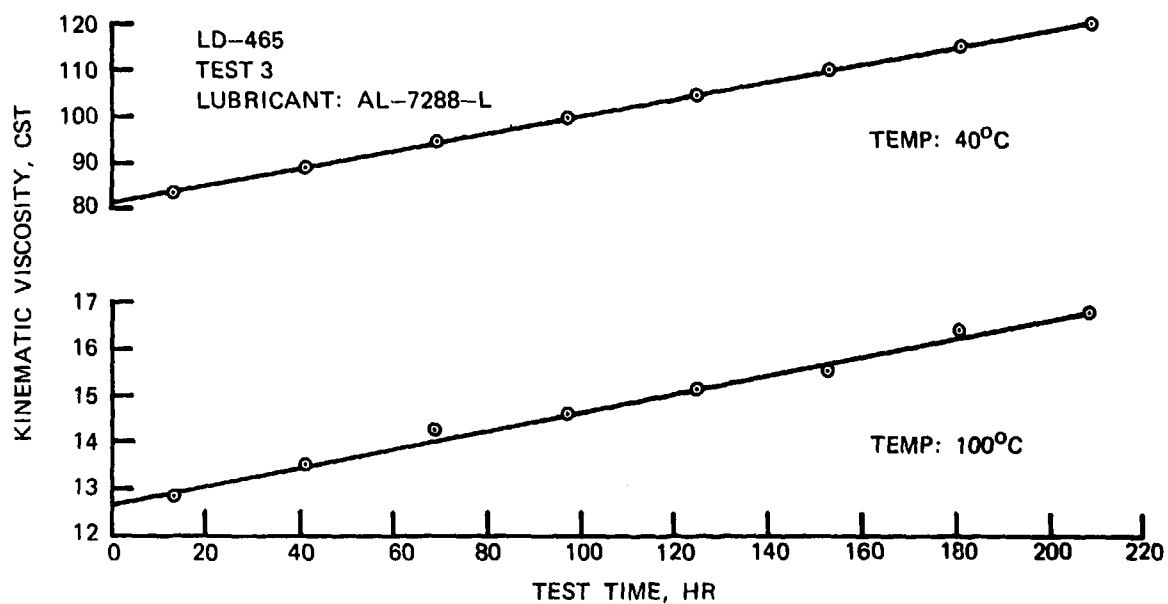
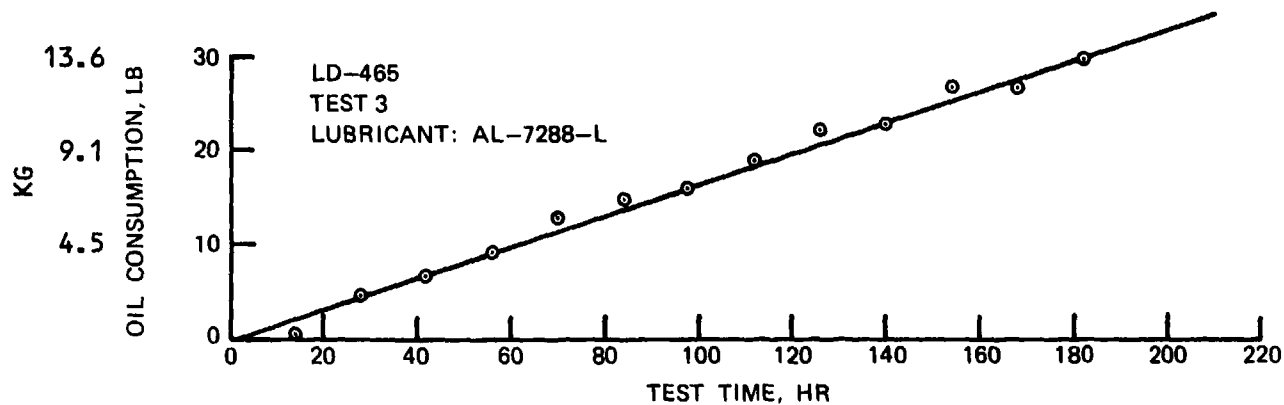
OIL CONSUMPTION, LB

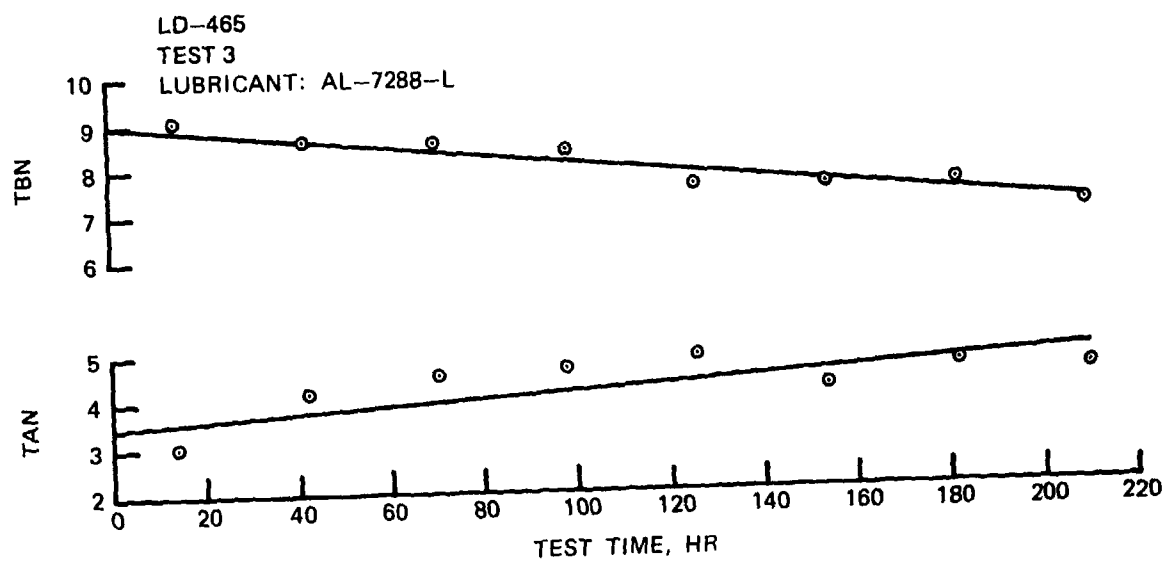
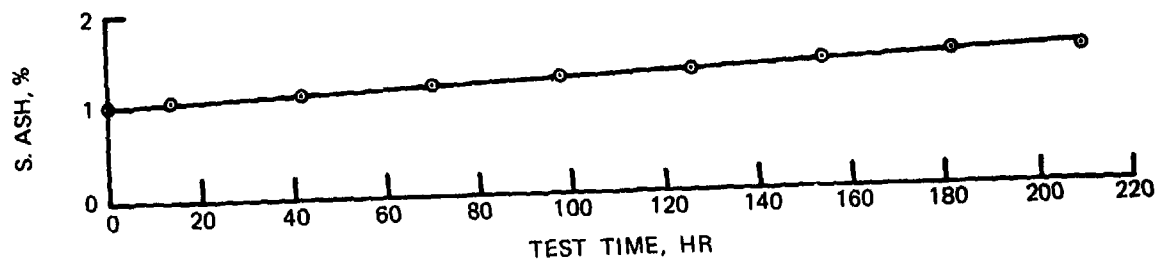
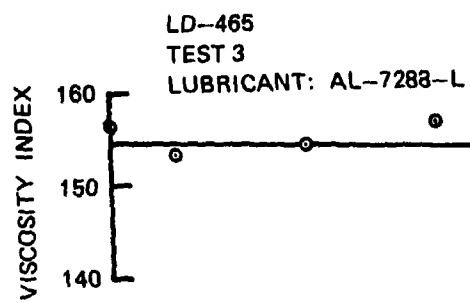
<u>Test Time, Hr.</u>	<u>Oil Consumed</u>	<u>Total Oil Consumed</u>
14	0.0	0.0
28	4.64	4.64
42	1.86	6.50
56	2.72	9.22
70	3.34	12.56
84	2.32	14.88
98	1.27	16.15
112	2.8	18.95
126	3.16	22.11
140	0.83	22.94
154	3.90	26.84
168	0.0	26.84
182	3.30	30.14
196	0.0	30.14

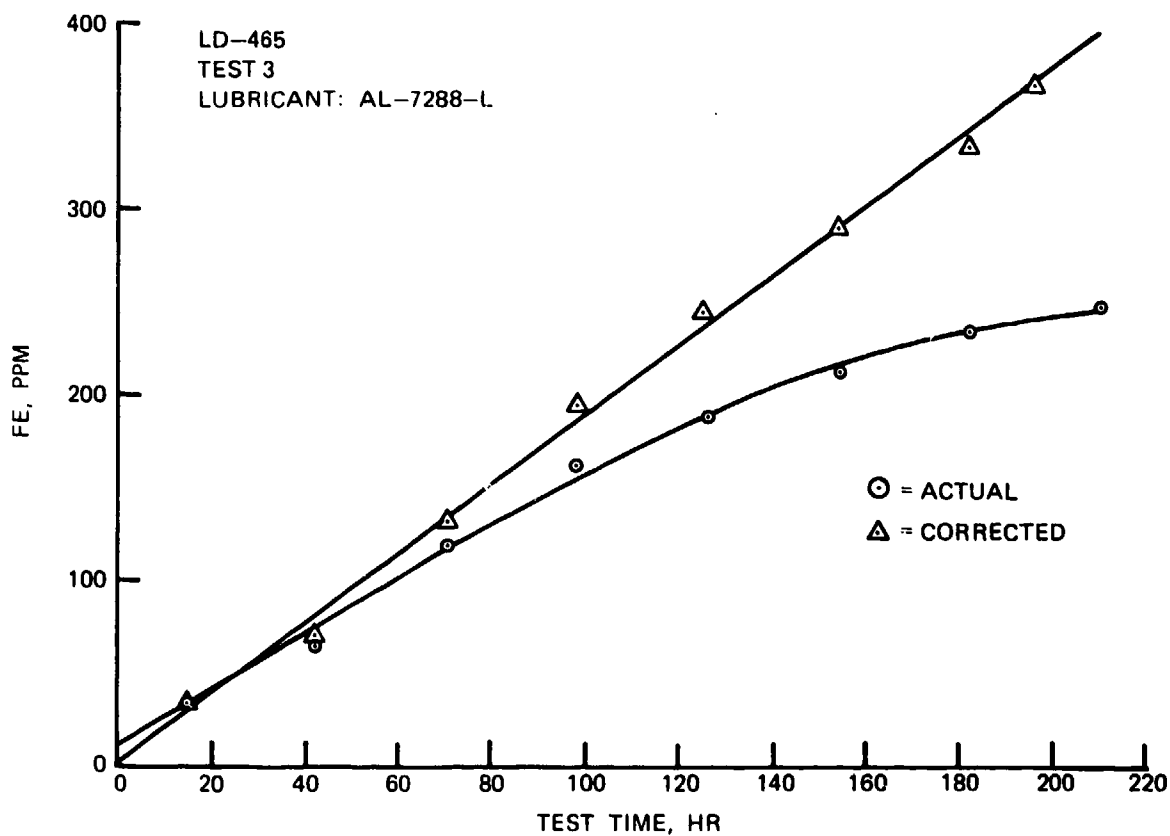
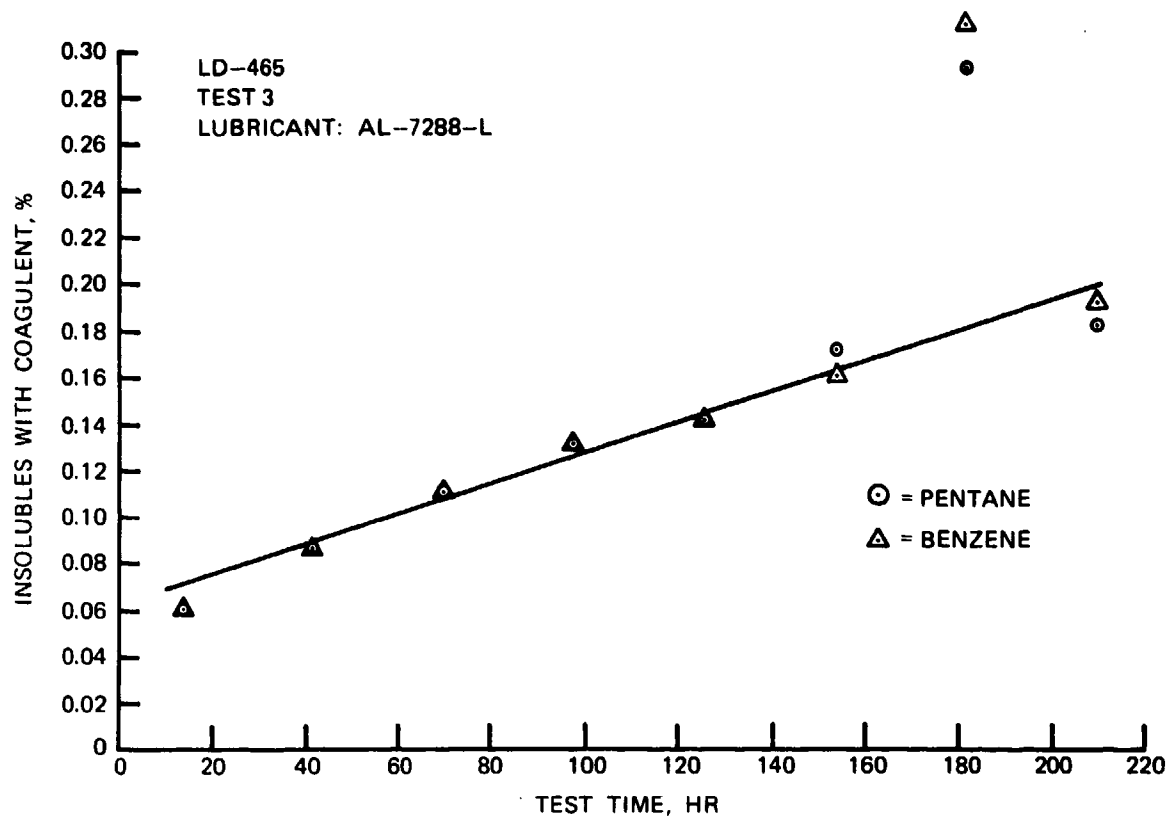
LD 465
TEST 3
LUBRICANT: AL-7288-L

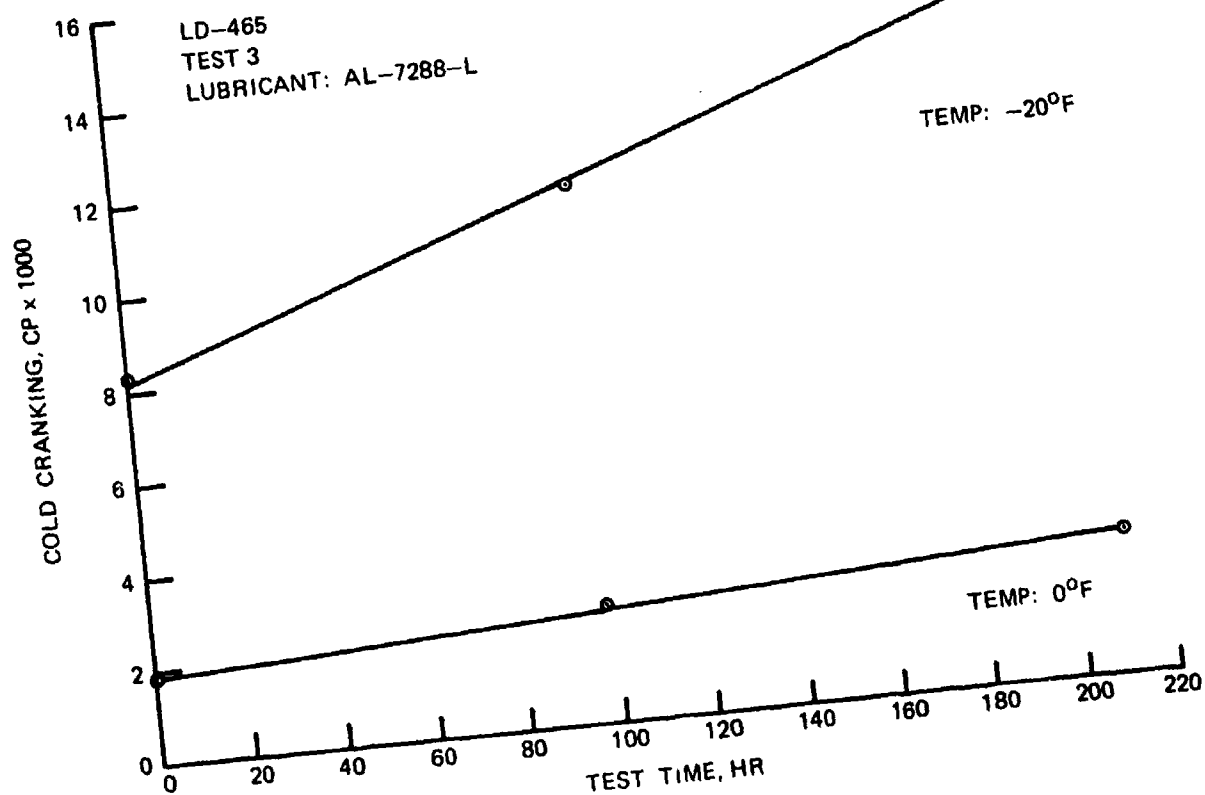
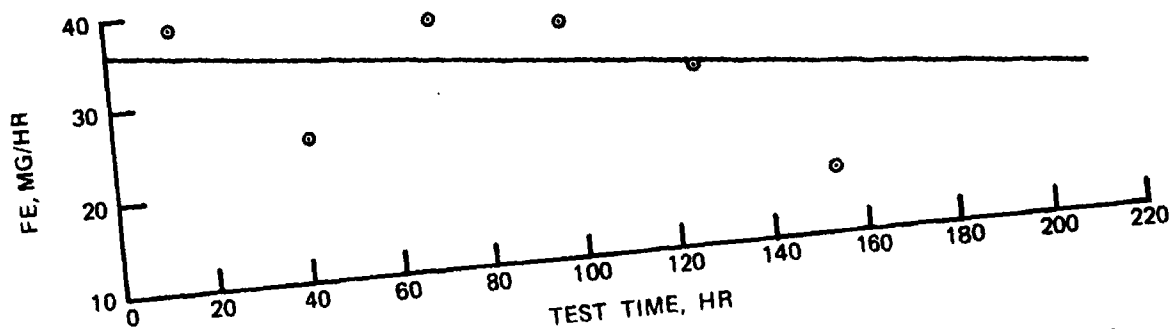
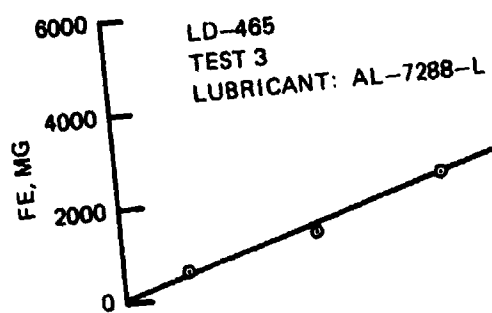
LUBRICANT ANALYSIS

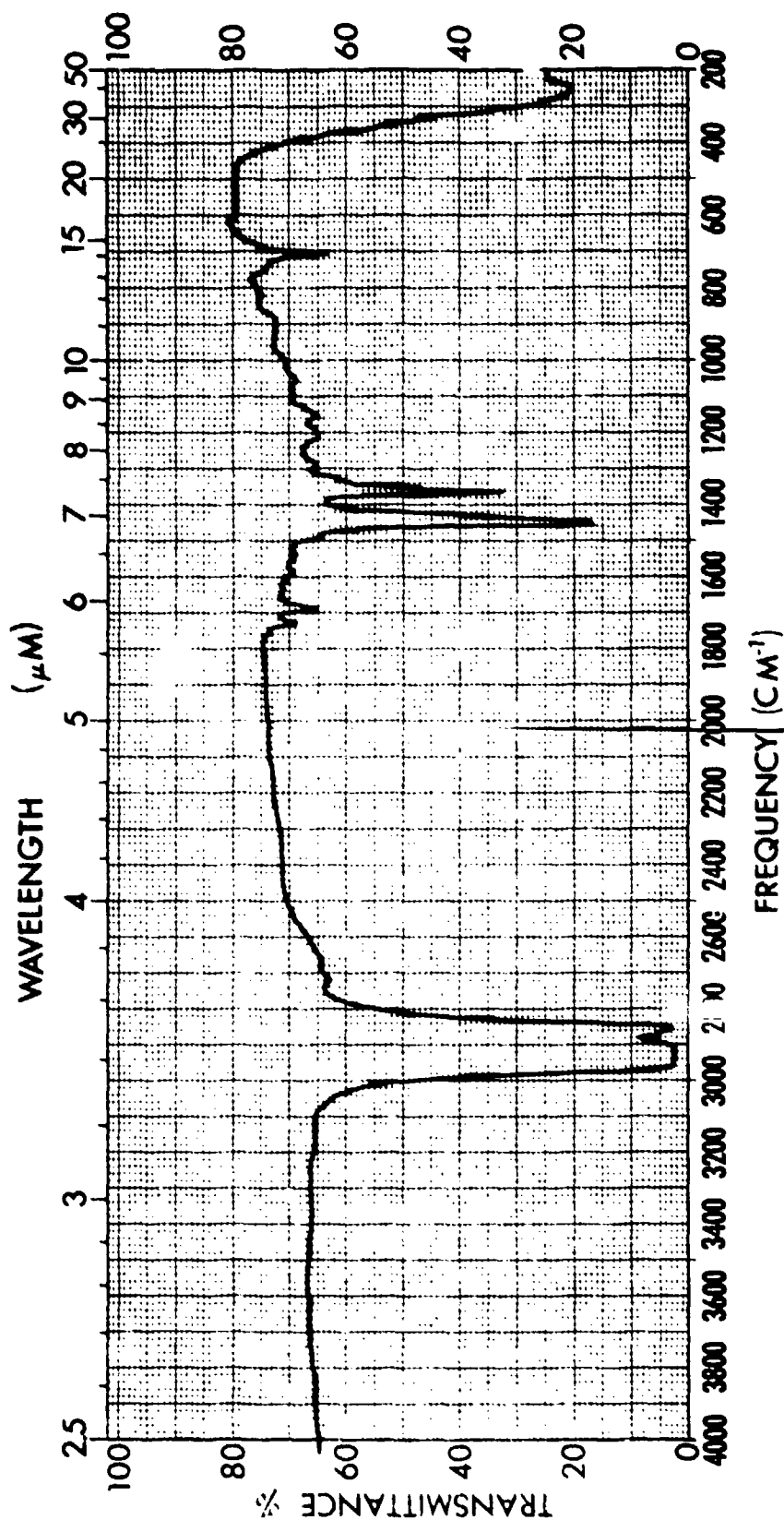
		Test Time (Hrs.)									
		0	14	42	70	98	126	154	182	210	
ASTM TEST METHOD	IR Trace No.										
D-445	K. Vis. Cs @ 40°C	81.64	83.26	88.84	94.35	99.79	105.21	110.64	115.02	120.62	
D-445	K. Vis. Cs @ 100°C	12.77	12.81	13.50	14.25	14.63	15.16	15.57	16.47	16.86	
D-2270-74	V.I.	156	153	154	156	152	151	149	155	152	
D-664	TAN	3.02	3.03	4.15	4.54	4.60	4.89	4.26	4.70	4.58	
D-2896	TBN	9.05	8.56	8.56	8.56	8.32	7.58	7.58	7.58	7.09	
D-874	S. Ash, %	0.99	1.04	1.13	1.20	1.25	1.30	1.40	1.42	1.47	
D-893	Pentane Insol. w/coag, %	---	0.06	0.09	0.11	0.13	0.14	0.17	0.29	0.18	
D-893	Benzene Insol. w/coag, %	---	0.06	0.09	0.11	0.13	0.14	0.16	0.31	0.19	
	Fe, ppm by XRF	---	33	65	118	162	188	212	233	247	
D-2602	Cold Cranking, 0°F, cp	1800				2510				3100	
D-2602	Cold Cranking, -20°F, cp	8300				11600				15800	



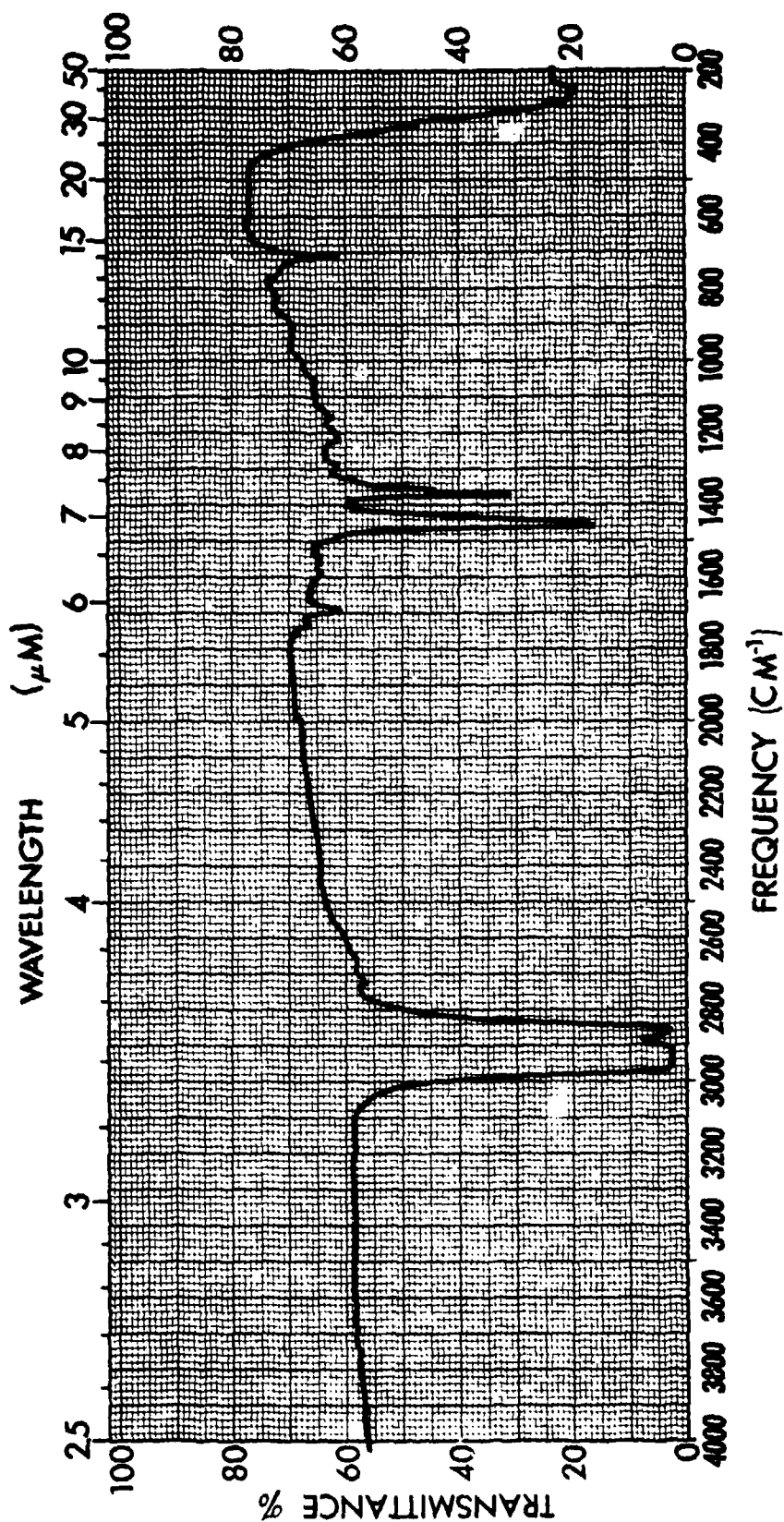




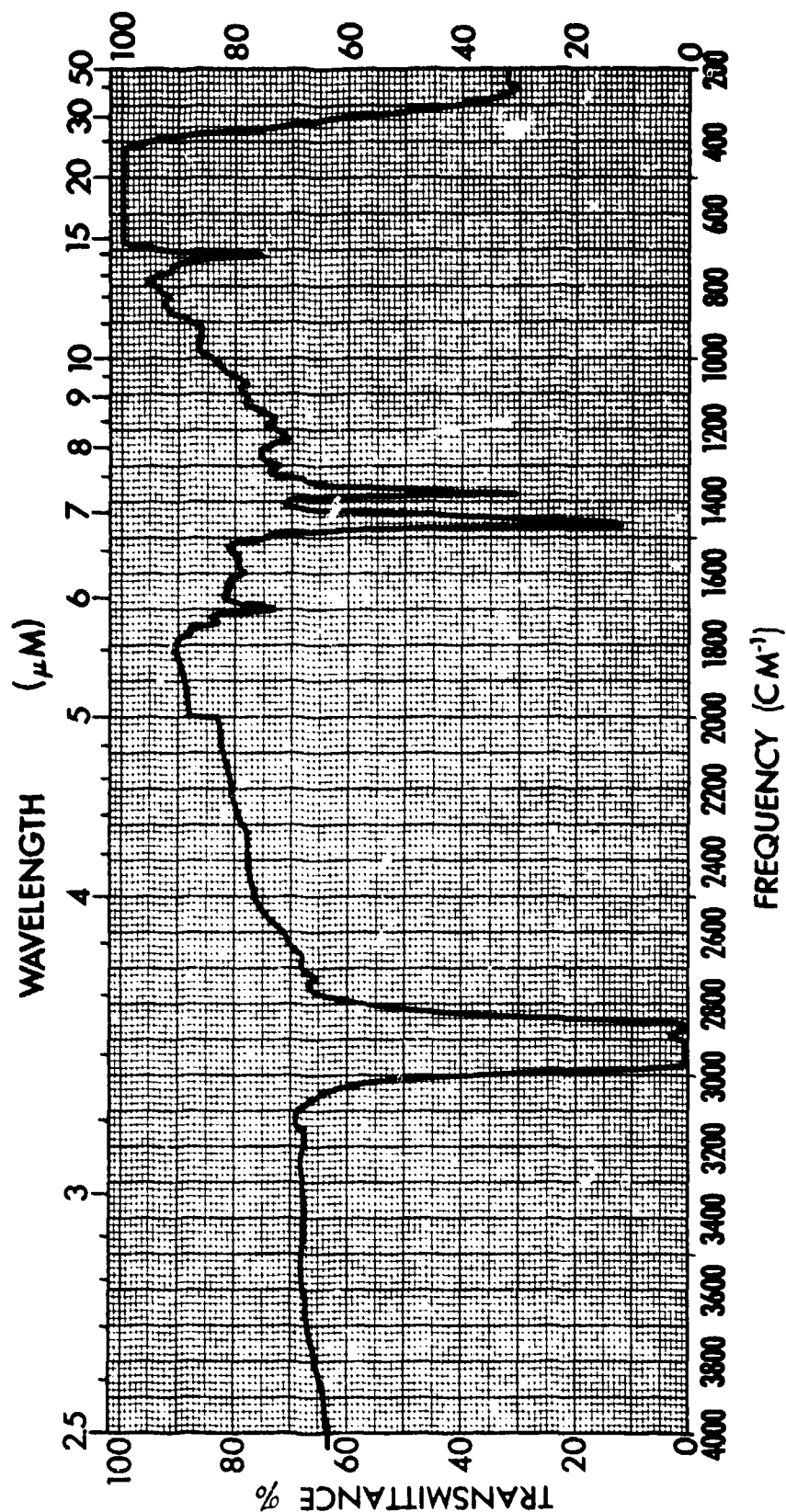




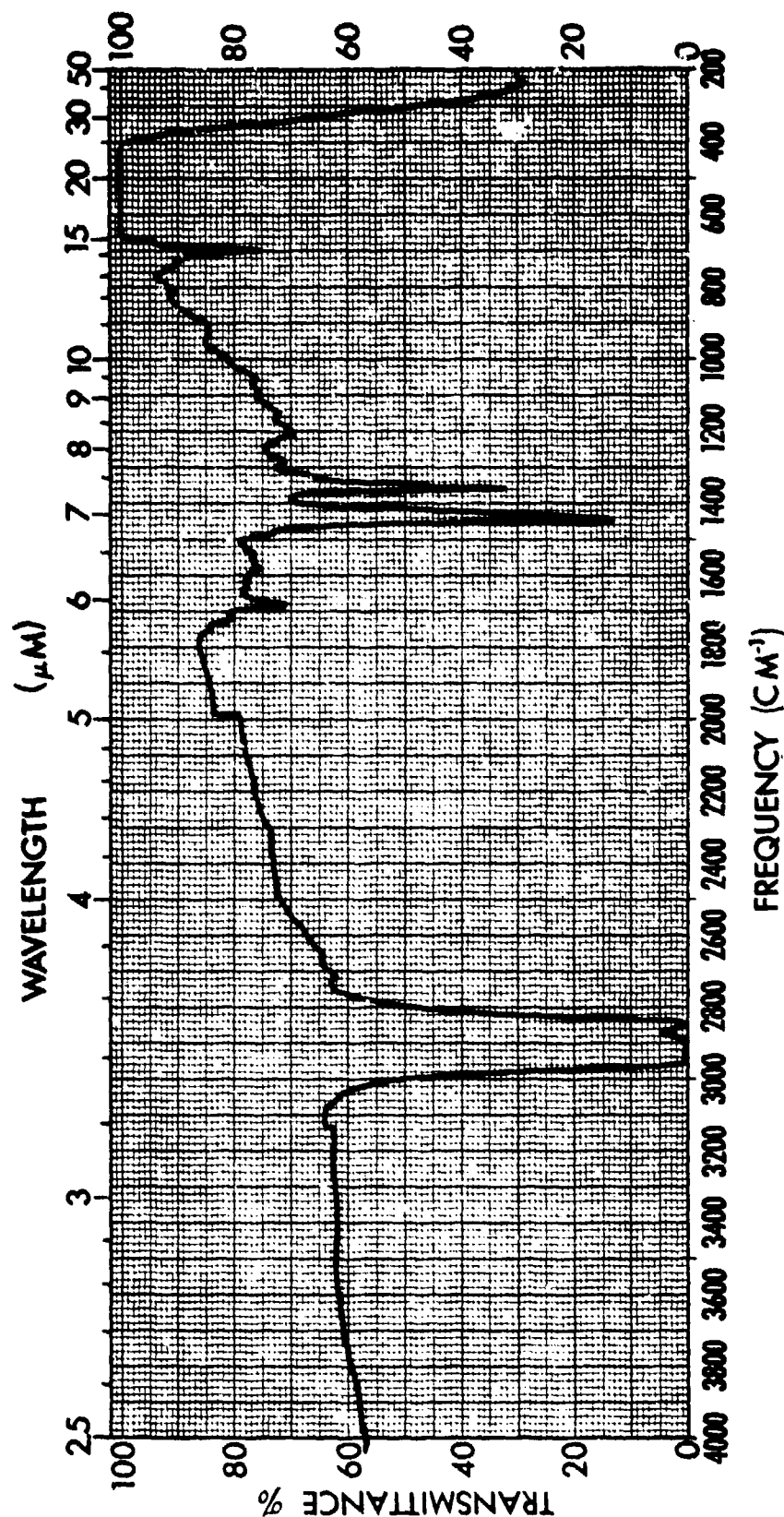
SPECTRUM NO. <u>1637</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-7288-L</u>	_____	1. _____	_____
<u>14 Hr Test #3</u>	PURITY _____	2. _____	_____
_____	PHASE _____	DATE <u>2/15/79</u>	_____
_____	THICKNESS <u>0.015</u>	OPERATOR <u>DDD</u>	_____



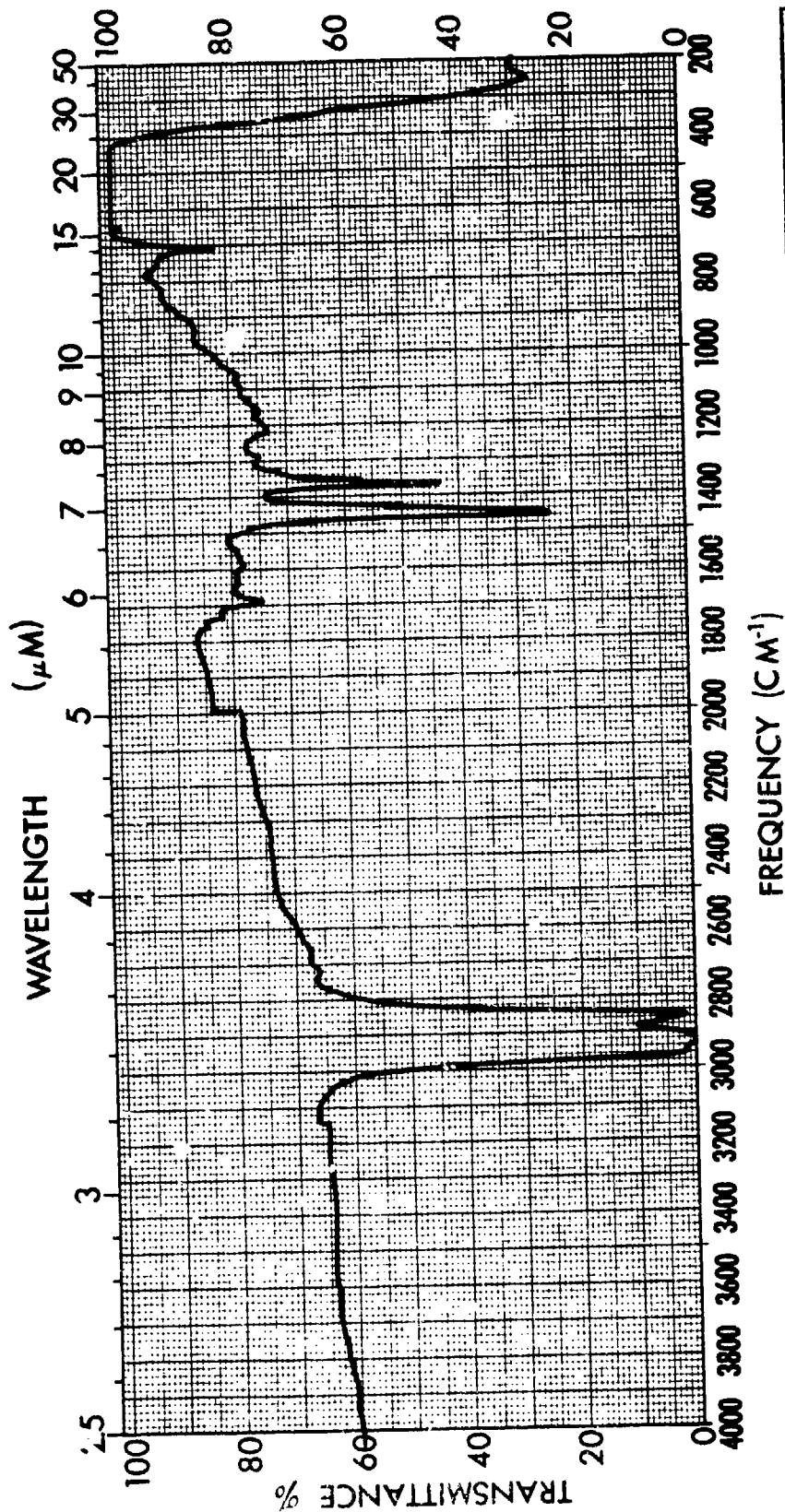
SPECTRUM NO. <u>1638</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-7288-L</u>	PURITY _____	1. _____	_____
42 Hr. Test No. 3	PHASE _____	2. _____	_____
	THICKNESS <u>0.015</u>	DATE <u>2/15/79</u>	_____
		OPERATOR <u>DDD</u>	_____



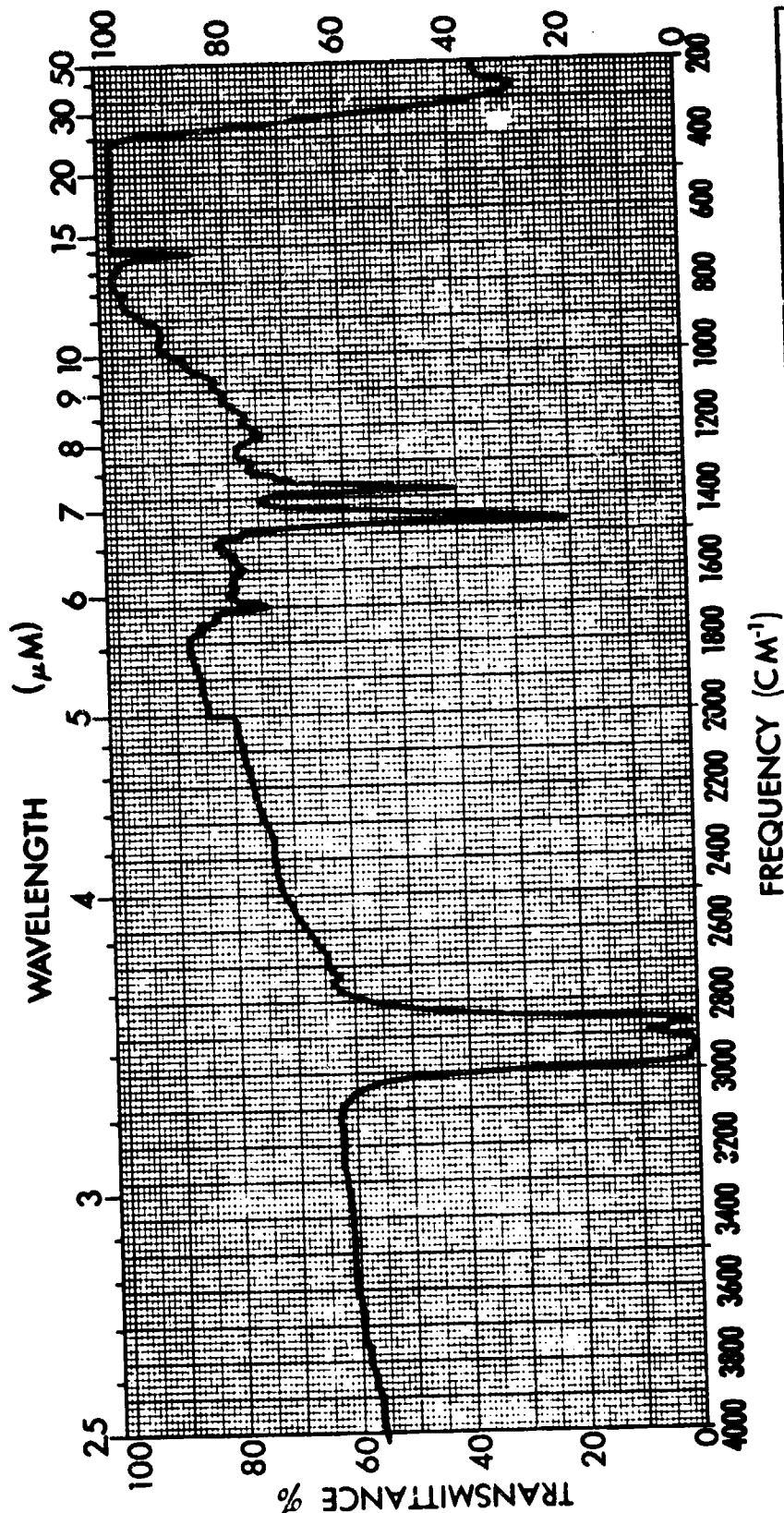
SPECTRUM NO. 1639	ORIGIN	LEGEND	REMARKS
SAMPLE AL-7288-L		1.	
40 Hr. Test No. 3	PURITY	2.	
	PHASE	DATE 2/26/79	
	THICKNESS 0.015	OPERATOR DDD	



SPECTRUM NO. <u>1640</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-7288-L</u>	1. _____	1. _____	
.98 Hr. Test No. <u>3</u>	PURITY _____	2. _____	
	PHASE _____	DATE <u>2/26/79</u>	
	THICKNESS <u>0.015</u>	OPERATOR <u>DDD</u>	

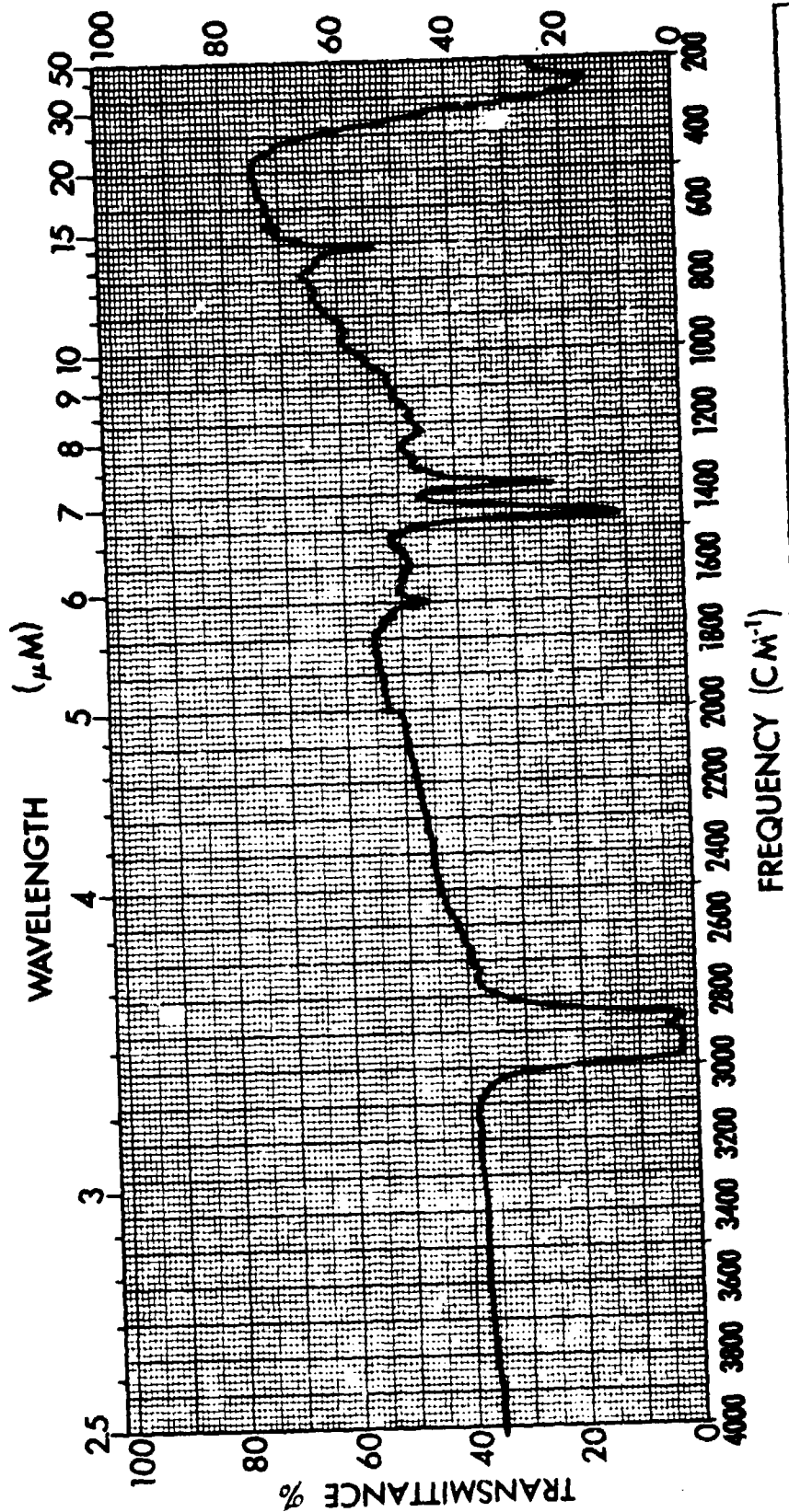


SPECTRUM NO. 1641	ORIGIN	LEGEND	REMARKS
SAMPLE AL-7288-L		1.	
126 Hr. Test No. 3	PURITY	2.	
	PHASE	DATE 2/26/79	
	THICKNESS 9.015	OPERATOR DDD	

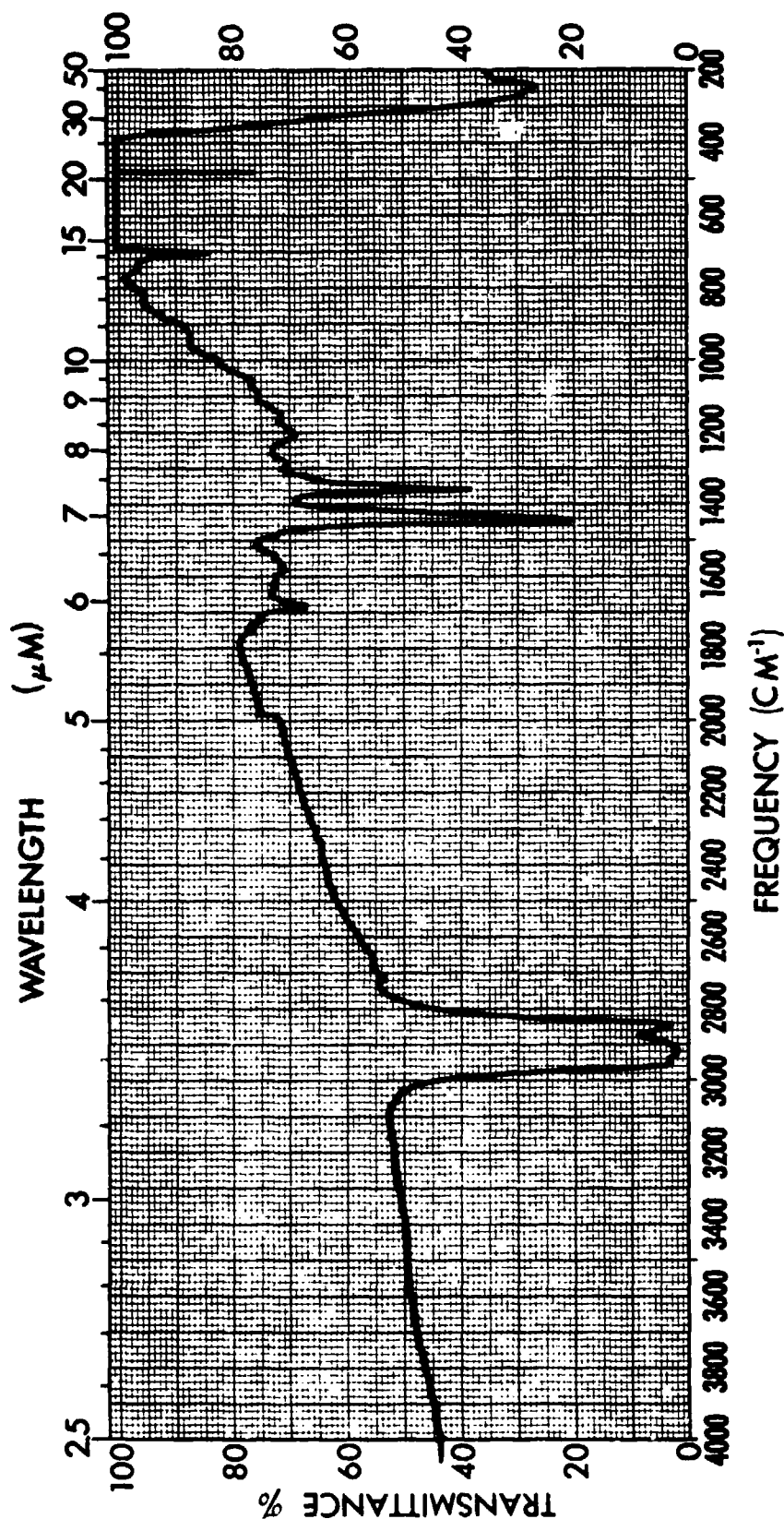


J-19

SPECTRUM NO. <u>1642</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-7288-L</u> 154 Hr. Test No. 3	PURITY _____	1. _____ 2. _____	_____
_____	PHASE _____	DATE <u>2/27/79</u>	_____
_____	THICKNESS <u>0.015</u>	OPERATOR <u>DDD</u>	_____



SPECTRUM NO. 1643	ORIGIN	LEGEND	REMARKS
SAMPLE AL-7288-L		1.	
182 Hr. Test #3	PURITY	2.	
	PHASE	DATE 3/1/79	
	THICKNESS 0.015	OPERATOR DDD	



SPECTRUM NO. <u>1644</u>	ORIGIN _____	LEGEND _____	REMARKS _____
SAMPLE <u>AL-7288-L</u>	PURITY _____	1. _____	_____
210 Hr. Test No. <u>3</u>	PHASE _____	2. _____	_____
_____	THICKNESS <u>0.015</u>	DATE <u>3/5/79</u>	_____
_____	OPERATOR <u>DDD</u>	_____	_____

TEST: 3
LUBRICANT: AL-7288-L

WEAR MEASUREMENTS

CYLINDER LINER BORE DIAMETER (INCHES)

	Longitudinal			Transverse		
	Before	After	Change	Before	After	Change
1) Top	4.5631	4.5571	-0.0060	4.5636	4.5580	-0.0056
Center	4.5632	4.5570	-0.0062	4.5640	4.5581	-0.0060
Bottom	4.5634	4.5572	-0.0062	4.5641	4.5582	-0.0059
2) Top	4.5627	4.5569	-0.0058	4.5637	4.5580	-0.0057
Center	4.5629	4.5566	-0.0063	4.5638	4.5579	-0.0059
Bottom	4.5630	4.5566	-0.0064	4.5638	4.5581	-0.0057
3) Top	4.5633	4.5574	-0.0059	4.5638	4.5584	-0.0054
Center	4.5634	4.5572	-0.0062	4.5635	4.5577	-0.0058
Bottom	4.5634	4.5574	-0.0060	4.5637	4.5577	-0.0060
4) Top	4.5633	4.5567	-0.0066	4.5634	4.5581	-0.0053
Center	4.5633	4.5567	-0.0066	4.5635	4.5578	-0.0057
Bottom	4.5634	4.5571	-0.0063	4.5636	4.5576	-0.0060
5) Top	4.5625	4.5570	-0.0055	4.5641	4.5584	-0.0057
Center	4.5628	4.5569	-0.0059	4.5644	4.5585	-0.0059
Bottom	4.5635	4.5573	-0.0062	4.5644	4.5585	-0.0059
6) Top	4.5632	4.5577	-0.0055	4.5639	4.5582	-0.0057
Center	4.5633	4.5575	-0.0058	4.5637	4.5578	-0.0059
Bottom	4.5637	4.5578	-0.0059	4.5637	4.5575	-0.0062

LD465

TEST: 3

LUBRICANT: AL-7288-L

WEAR MEASUREMENTS

PISTON RING END GAP (INCHES)

Ring Number*	PISTON NUMBER					
	1	2	3	4	5	6
1) Before Test	0.025	0.024	0.020	0.024	0.024	0.024
After Test	0.030	0.028	0.030	0.028	0.028	0.028
Change	0.005	0.004	0.010	0.004	0.004	0.004
2) Before Test	0.024	0.022	0.021	0.023	0.024	0.023
After Test	0.028	0.028	0.030	0.030	0.028	0.028
Change	0.004	0.006	0.009	0.007	0.004	0.005
3) Before Test	0.020	0.020	0.019	0.024	0.022	0.021
After Test	0.020	0.022	0.024	0.022	0.026	0.025
Change	0.000	0.002	0.005	-0.002	0.004	0.004
4) Before Test	0.016	0.018	0.020	0.021	0.020	0.023
After Test	0.018	0.016	0.024	0.024	0.026	0.025
Change	0.002	-0.002	0.004	0.003	0.006	0.002

* From Top of Piston

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Wheeled
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-7288-L

RATER E.L. DATE 3-13-79
 LABORATORY TEST NUMBER 3
 STAND NO. 6 ENGINE NO. 465
 FUEL AL-8060-F

PISTON NO. 1

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				NO. 1 GROOVE, VOLUME-%	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC 1.00					15	15.00				
	MHC 0.75										
	MC 0.50					70	35.00				
	LC 0.25	25	6.25				5	1.25			
	VLC 0.15						5	.75			
CARBON RATING		6.25				50.00	2.00				
LACQUER	BL 0.100	75	7.50			10	1.00				
	DBrL 0.075										
	AL 0.050		100	5.00	100					100	5.00
	LAL 0.025				100	5	.125	90	2.25	100	2.50
	VLAL 0.010										
LACQUER RATING		7.50	5.00	5.00	2.50	1.125	2.25	2.50	2.50	5.00	
CLEAN 0											
ZONAL RATING											
LOCATION FACTOR											
WEIGHTED RATING		13.75	5.00	5.00	2.50	51.125	4.25	2.50	2.50	5.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Wheel
 TEST HOURS 210
 TEST LABORATORY AFRL
 LUBRICANT AL-7288-L

RATER EL DATE 3-13-79
 LABORATORY TEST NUMBER 3
 STAND NO. 6 ENGINE NO. 465
 FUEL AL-8060-F

PISTON NO. 2

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC	1.00									
	MHC	0.75									
	MC	0.50	65	32.50							
	LC	0.25	10	2.50		80	40.00				
	VLC	0.15									
LACQUER	CARBON RATING	35.00				40.00					
	BL	0.100	2.5	2.50	100	10.00	100	10.00	10.00		
	DBL	0.075				10	1.00	15	1.50		
	AL	0.050				5	.375				
	LAL	0.025						85	2.125	100	2.50
CLEAN	VIAL	0.010								100	5.00
	RL	0.001				5	.005				
	LACQUER RATING	2.50	10.00	10.00	5.00	1.380	3.625	2.50	2.50	5.00	
	CLEAN 0										
	ZONAL RATING										
LOCATION FACTOR											
WEIGHTED RATING		37.50	10.00	10.00	5.00	41.380	3.625	2.50	2.50	5.00	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 3

TEST PROCEDURE Wheel

TEST HOURS 210

TEST LABORATORY AFRL

LUBRICANT AL-7288-L

RATER E.L. DATE 3-13

LABORATORY TEST NUMBER 3

STAND NO. 6 ENGINE NO. 465

FUEL AI-8060-F

LUBRICANT AL-7288-L												FUEL AI-8060-F												NO. 1 GROOVE, VOLUME %							
																								PISTON WTD* RATING				96.250			
DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN												
			NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4																	
AREA % DEMERIT			AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT	AREA % DEMERIT										
CARBON			HC 1.00																												
			MHC 0.75																												
			MC 0.50																												
			LC 0.25	40	10.00																										
			VLC 0.15																												
			CARBON RATING	10.00																											
			BL 0.100	60	6.00																										
			DBrL 0.075																												
			AL 0.050		100	5.00	100	5.00	100	5.00																					
			LAL 0.025																												
			VLAL 0.010																												
			RL 0.001																												
			LACQUER RATING	6.00	5.00	5.00	5.00	5.00	5.00	.25	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00										
			CLEAN 0																												
			ZONAL RATING																												
			LOCATION FACTOR																												
			WEIGHTED RATING	16.00	5.00	5.00	5.00	5.00	5.00	45.25	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00										

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Wheel ed 210 AFRL AL-7288-L
 TEST HOURS 210 AFRL AL-7288-L
 TEST LABORATORY AFRL AL-7288-L
 LUBRICANT AL-7288-L
 RATER E.L. DATE 3-13-79
 LABORATORY TEST NUMBER 3 465
 STAND NO. 6 ENGINE NO. 465
 FUEL AL-8060-F
 PISTON NO. 4

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				NO. 1 GROOVE, VOLUME-%	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
CARBON	HC 1.00										
	MHC 0.75										
	MC 0.50	50	25.00			90	45.00				
	LC 0.25										
	VLC 0.15										
CARBON RATING		25.00				45.00					
LACQUER	BL 0.100	50	5.00	100	10.00		10	1.00			
	DBL 0.075										
	AL 0.050				100	5.00	90	45.00	100	5.00	100
	LAL 0.025					10	.25				
	VLAL 0.010										
LACQUER RATING		5.00	10.00	10.00	5.00	.25	46.00	5.00	5.00	5.00	5.00
CLEAN 0											
ZONAL RATING											
LOCATION FACTOR											
WEIGHTED RATING		30.00	10.00	10.00	5.00	45.25	46.00	5.00	5.00	5.00	5.00

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 5

TEST PROCEDURE WheelEd
 TEST HOURS 210
 TEST LABORATORY AFLRL
 LUBRICANT AL-7288-1

RATER E. L. DATE 3-13-79
 LABORATORY TEST NUMBER 3
 STAND NO. 6 ENGINE NO. 465
 FUEL AL-8060-F

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	UNDER-CROWN
		AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT		
CARBON	HC 1.00	5	5.00								
	MHC 0.75										
	MC 0.50	5	2.50			90	45.00				
	LC 0.25	15	3.75								
	VLC 0.15										
LACQUER	CARBON RATING	11.25				45.00					
	BL 0.100	75	7.50	100	10.00			20	2.00		
	DBrL 0.075										
	AL 0.050			100	5.00			75	3.75		100
	LAL 0.025										
LACQUER	VLAL 0.010					10	.100				
	RL 0.001										
	LACQUER RATING	7.50	10.00	5.00	5.00	.100	5.75	2.50	2.50	2.50	5.00
	CLEAN 0										
	ZONAL RATING										
LOCATION FACTOR											
WEIGHTED RATING		18.75	10.00	5.00	5.00	45.100	7.00	2.50	2.50	2.50	5.00

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

RATER E.L. DATE 3-13-79
 LABORATORY TEST NUMBER 3
 STAND NO. 6 ENGINE NO. 465
 FUEL AL-8060-F

PISTON NO. 6

TEST PROCEDURE Wheelled
 TEST HOURS 210
 TEST LABORATORY AYRL
 LUBRICANT AL-7288-L

NO. 1 GROOVE, VOLUME-%	104.76
PISTON WTD* RATING	

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES				LANDS				UNDER-CROWN				
			NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2			
CARBON	HC	1.00													
	MHC	0.75													
	MC	0.50													
	LC	0.25	100	25.00											
	VLC	0.15													
	CARBON RATING		25.00												
LACQUER	BL	0.100													
	DBrL	0.075													
	AL	0.050		100	5.00	100	5.00							100	5.00
	LAL	0.025													
	VLAL	0.010													
	RL	0.001													
LACQUER RATING			5.00	5.00	5.00	5.00									
CLEAN		0													
ZONAL RATING															
LOCATION FACTOR															
WEIGHTED RATING			25.00	5.00	5.00	5.00	5.00							2.50	5.00

*WEIGHTED TOTAL DEPOSITS

TEST 3

RING DEPOSITS

Engine Model Continental LD-465 Serial No. 390-4343 Date 3-13-79
 Fuel AL-8060-F Lubricant AL-7288-L Observer Lyons

Cylinder Number		1		2		3		4		5		6	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Piston Ring	Top	1	0	0	30	0	15	0	15	0	5	0	20
		2	0	0	20	0	10	0	10	0	5	0	10
		3	0	0	95	0	95	0	95	0	95	0	90
		4	0	0	0	0	0	0	0	0	0	0	0
ID		1	0	0	100	0	100	0	100	0	75	0	0
		2	0	0	100	0	100	0	100	0	100	0	100
		3	0	0	100	0	100	0	100	0	100	0	100
		4	0	0	0	0	0	0	0	0	0	0	0
Bottom		1	0	0	0	0	5	0	5	0	0	0	0
		2	0	0	50	0	0	0	20	0	10	0	20
		3	0	0	75	0	25	0	85	0	85	0	60
		4	0	0	0	0	0	0	0	0	0	0	0

See pages 4, 36 and 37 of Manual. Areas previously rated for carbon, rate 0 for lacquer

Test 3
RING FACE CONDITION

Engine Model Continental LD-465 Serial No. 390-4343 Date 3-13-79
 Fuel AL-8060-F Lubricant AL-7288-L Observer Lyons

	Cylinder Number					
	1	2	3	4	5	6
First Ring	N	N	N	N	N	N
Second Ring	N	N	N	N	N	N
Third Ring	N	N	N	N	N	N
Fourth Ring	N	N	N	N	N	N
Oil Ring Slots-% Open	100	←				→

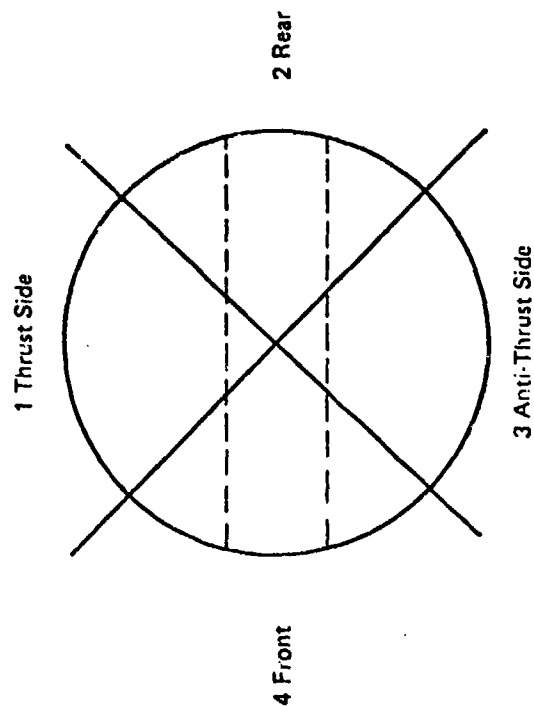
Pages 1 and 2 and 59 through 65 of Manual.
 N = NORMAL

PISTON GROOVE INSIDE DIAMETER-% RING SUPPORTING CARBON

Test 3

Engine Model Continental LD-465 Serial No. 390-4343 Date 3-13-79
 Fuel AL-8060-F Lubricant AL-7288-L Observer Lyons

Piston Ring	Quadrant	Piston Number					
		1	2	3	4	5	6
1	1	0	0	0	5	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0



PISTON SURFACE CONDITION Test 3

Engine Model Continental LD-465 Serial No. 390-4343 Date 3-13-79
 Fuel AL-8060-F Lubricant AI-7288-L Observer Lyons

	Piston Number					
	1	2	3	4	5	6
Top Land	N	N	N	N	N	N
Skirt	N	N	N	N	N	N
Piston Pin	N	N	N	N	N	N

Pages 1 through 2 and 59 through 65 of Manual.
 N = NORMAL

VALVE SURFACE CONDITIONS Test 3

Engine Model Continental LD-465 Serial No. 390-4343 Date 3-13-79
 Fuel AL-8060-F Lubricant AL-7288-L Observer Lyons

	Intake						Exhaust					
	i	2	3	4	5	6	1	2	3	4	5	6
Freedom in Guide	F	F	F	F	F	F	F	F	F	F	F	F
Head	N	N	N	N	N	N	N	N	N	N	N	N
Face	N	N	N	N	N	N	N	N	N	N	N	N
Seat	N	N	N	N	N	N	N	N	N	N	N	N
Stem	N	N	N	N	N	N	N	N	N	N	N	N
Tip	N	N	N	N	N	N	N	N	N	N	N	N

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

Tulip Deposit 3.0 2.5 3.5 3.5 3.5 3.0 2.0 .5 .5 .5 .5 .5

F = FREE

N = NORMAL

CYLINDERS Test 3

Engine Model Continental LD-465 Serial No. 390-4343 Date 3-1-79
 Fuel AL-8060-F Lubricant AL-7288-L Observer Lyons

Cylinder Number													
		1L		2L		3L		41R		52R		6 3R	
Deposits	Cylinder Head	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Cylinders	ART	100	0	100	0	90	10	100	0	100	0	100	0
	RTA	0	100	0	100	0	100	0	100	0	100	0	100
	BRT	0	100	0	100	0	100	0	100	0	100	0	100
Surface Condition													
Cylinders	RTA	LT Scratches	LT Scratches	LT Scratches	LT Scratches	MED Scuff	LT Scuff	LT Scratches	LT Scuff	LT Scratches	LT Scuff	LT Scratches	LT Scuff
	BRTA	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scuff	LT Scuff	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches	LT Scratches

Carbon and Ash: Use Volume Factor Pages 5 and 40 through 47 of Manual.

Indicate H, M, or S

Lacquer: Use Pages 4, 36 and 37

For Surface Condition—See Pages 1, 2, 16 through 23 and 54 through 65.

SURFACE CONDITION Test 3

Engine Model Continental LD 465 Serial No. 390-4343 Date 3-13-79
 Fuel AL-8060-F Lubricant AL-7288-L Observer Lyons

Bearing No.	1	2	3	4	5	6	7
Main-Bearing	N	N	N	N	N	N	N
-Journal	N	N	N	N	N	N	N
Rod-Bearing	N	N	N	N	N	N	
-Journal	N	N	N	N	N	N	
Piston Pin	N	N	N	N	N	N	
Bushing	N	N	N	N	N	N	

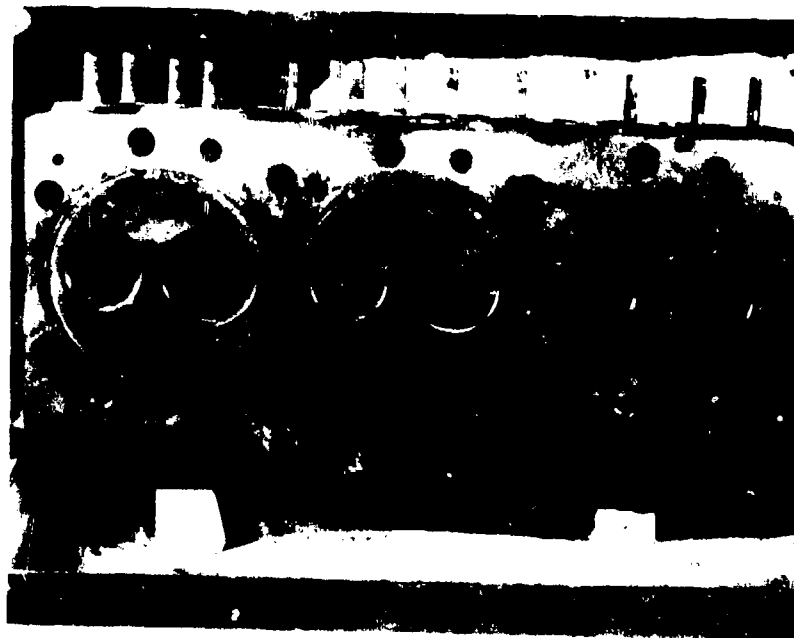
Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

N = NORMAL

LD-465
TEST 3
AFTER TEST CONDITION OF CYLINDER HEADS



CYLINDERS 3, 2, AND 1



CYLINDERS 6, 5, AND 4

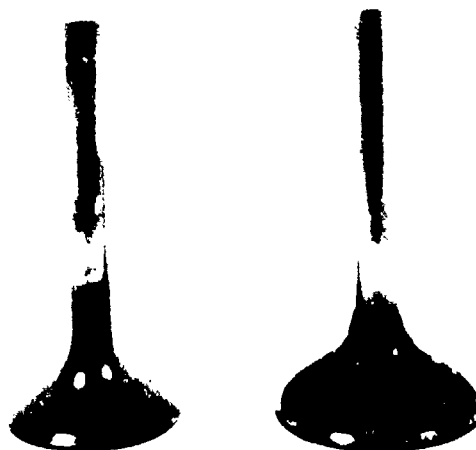
LD-465
TEST 3
AFTER TEST CONDITION OF NO. 1 PISTON AND VALVES



PISTON THRUST SIDE

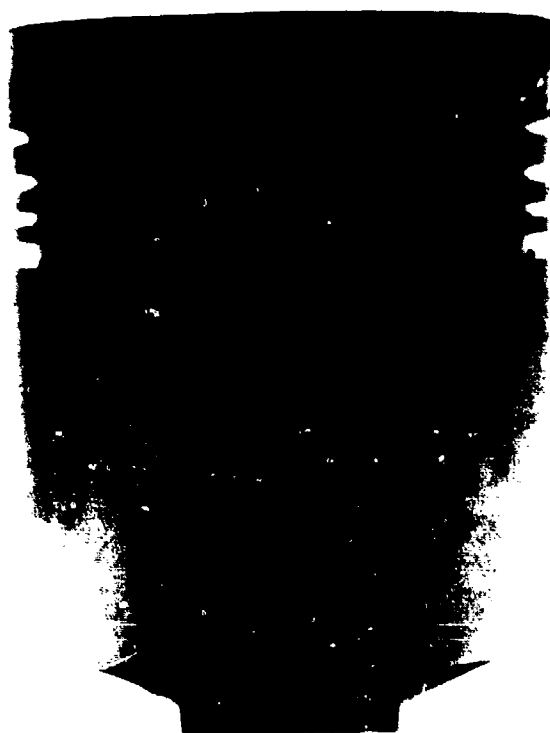


PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

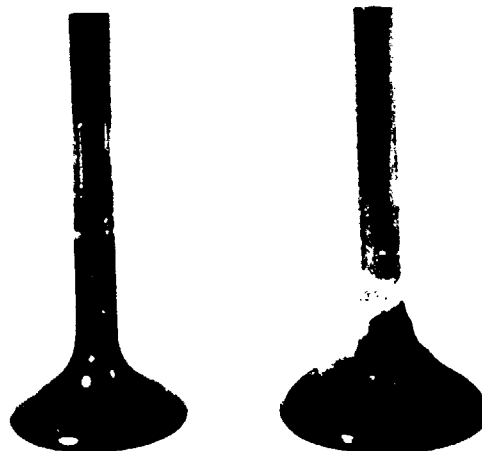
LD-465
TEST 3
AFTER TEST CONDITION OF NO. 2 PISTON AND VALVES



PISTON THRUST SIDE



PISTON ANTI-THRUST SIDE

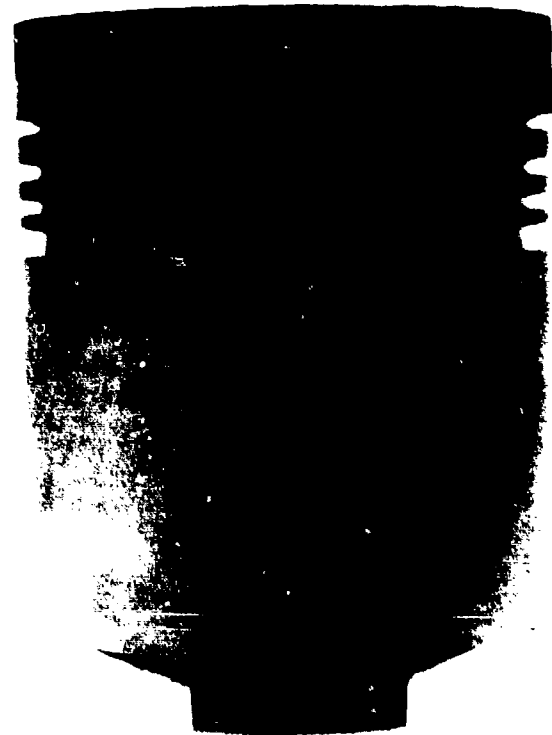


INTAKE AND EXHAUST VALVES

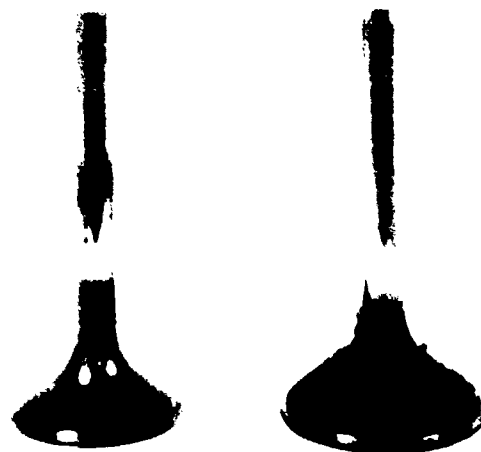
LD-465
TEST 3
AFTER TEST CONDITION OF NO. 3 PISTON AND VALVES



PISTON THRUST SIDE



PISTON ANTI-THRUST SIDE

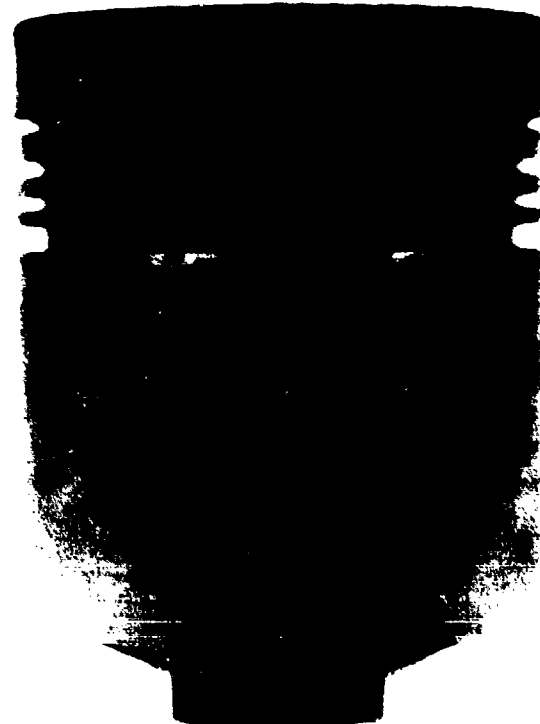


INTAKE AND EXHAUST VALVES

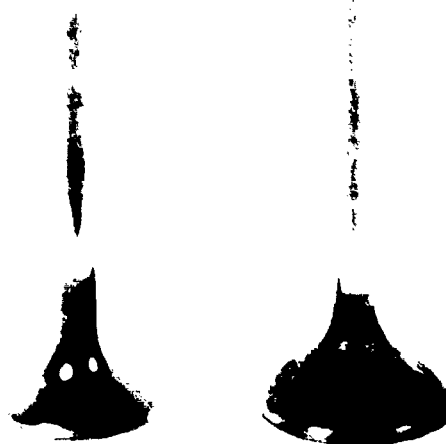
LD-465
TEST 3
AFTER TEST CONDITION OF NO. 4 PISTON AND VALVES



PISTON THRUST SIDE

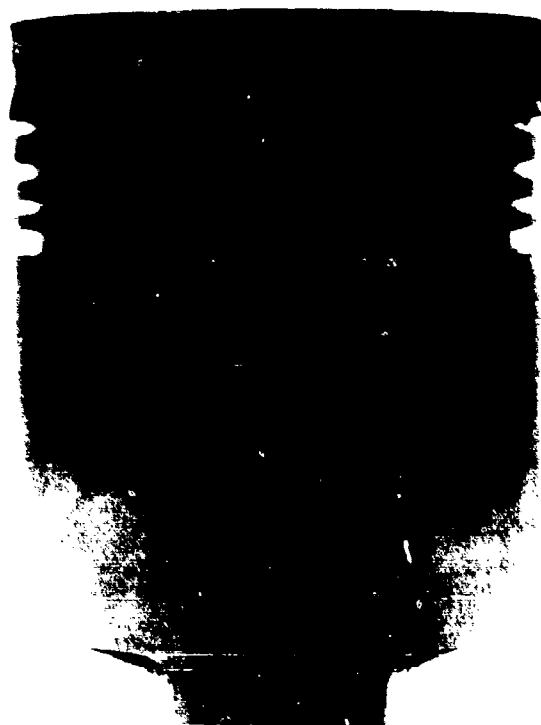


PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

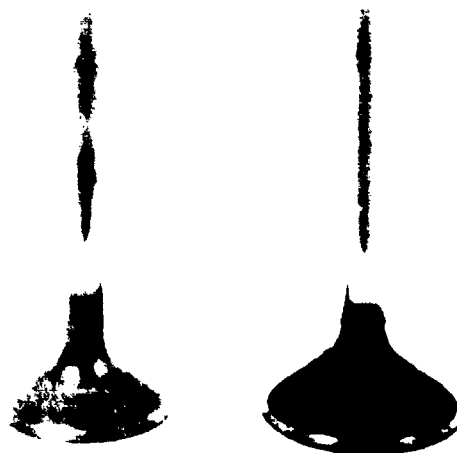
LD-465
TEST 3
AFTER TEST CONDITION OF NO. 5 PISTON AND VALVES



PISTON THRUST SIDE

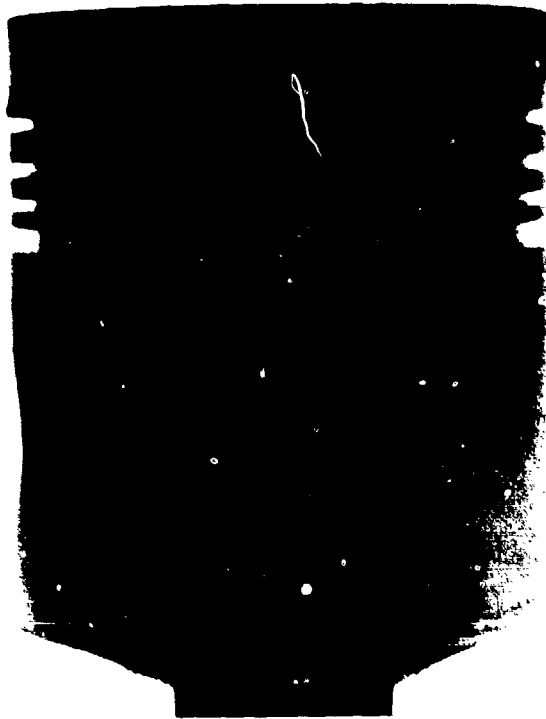


PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

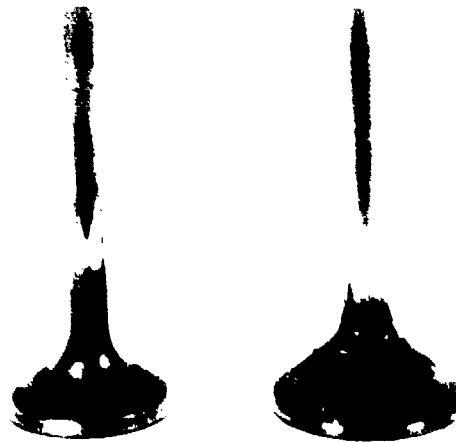
LD-465
TEST 3
AFTER TEST CONDITION OF NO. 6 PISTON AND VALVES



PISTON THRUST SIDE

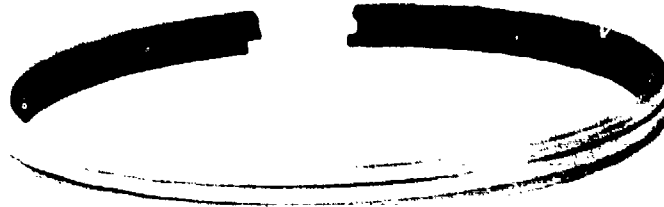


PISTON ANTI-THRUST SIDE



INTAKE AND EXHAUST VALVES

LD-465
TEST 3
AFTER TEST CONDITION OF PISTON RINGS

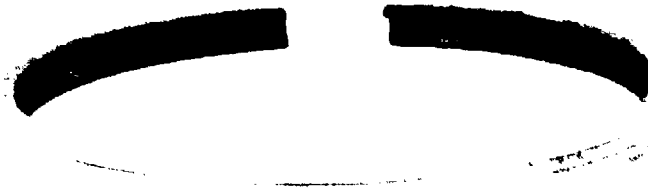


CYLINDER 1

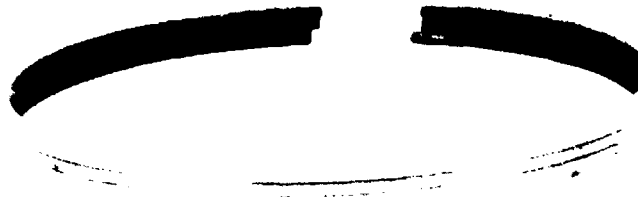


CYLINDER 2

LD-465
TEST 3
AFTER TEST CONDITION OF PISTON RINGS

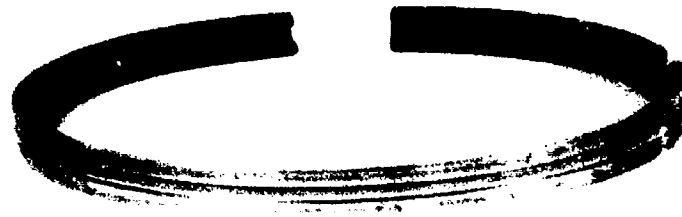


CYLINDER 3



CYLINDER 4

LD-465
TEST 3
AFTER TEST CONDITION OF PISTON RINGS



CYLINDER 5



CYLINDER 6

APPENDIX K

ENGINE-LUBRICANT COMPATIBILITY TEST #4
210-HOUR WHEELED-VEHICLE CYCLE
USING LDT-465-1C DIESEL ENGINE

**ENGINE-LUBRICANT COMPATIBILITY TEST
210-HOUR WHEELED-VEHICLE CYCLE
USING LDT-465-1C DIESEL ENGINE**

**Test Lubricant: AL-8930-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 4
Date Completed: 14 January 1980**

Conducted for

**U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia**

by

**U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284**

LDT-465-1C
TEST 4
ENGINE REBUILD MEASUREMENTS

	Inches			<u>Specified Limits</u>
	<u>Min</u>	<u>Max</u>	<u>Avg</u>	
<u>Cylinder Liners (Installed)</u>				
Inside Diameter	4.5621	4.5644	4.5634	4.5630-4.5645
Out of Round	0.0002	0.0016	0.0010	0.0015 max
 Piston Skirt Diameter (at bottom)	 4.5554	 4.5558	 4.5556	 4.5530-4.5580
 <u>No. 1 Ring</u>				
End Gap	0.022	0.024	0.023	0.022-0.035
 <u>No. 2 Ring</u>				
End Gap	0.021	0.025	0.023	0.022-0.035
 <u>No. 3 Ring</u>				
End Gap	0.018	0.021	0.020	0.010-0.028
Side Clearance	0.002	0.002	0.002	0.0025-0.0045
 <u>No. 4 Ring</u>				
End Gap	0.018	0.022	0.020	0.010-0.028
Side Clearance	0.0015	0.0015	0.0015	0.0010-0.0035

LDT-465-1C 210-HOUR WHEELED-VEHICLE CYCLE ENDURANCE TEST

TEST 4

OPERATING CONDITIONS SUMMARY

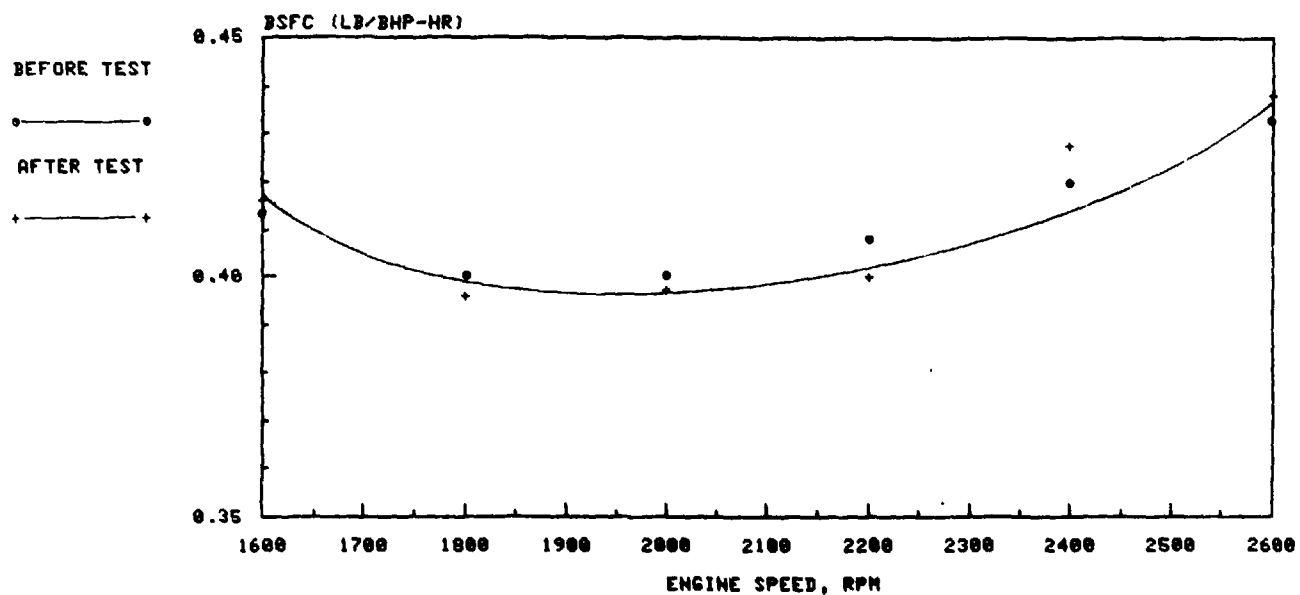
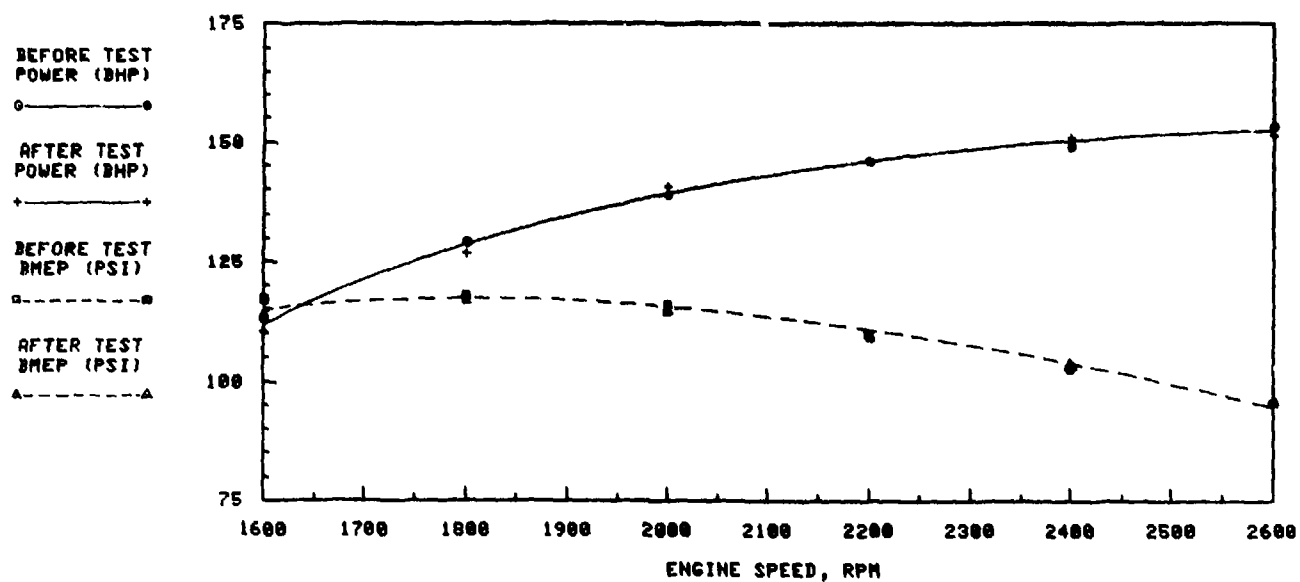
Fuel: AL-8764-F

Lubricant: AL-8980-L

	Power Mode			Idle Mode
	Min	Max	Avg	Avg
Engine Speed, rpm	2602	2614	2608	803
Torque, ft-lb (N-m)	308(418)	316(428)	311(422)	10(14)
Observed Power, Bhp (kW)	151(113)	158(118)	154(115)	1.5(1.1)
Fuel Consumption, lb/hr (kg/hr)	66.2(30.1)	67.3(30.6)	66.8(30.3)	7.1(3.2)
BSFC, lb/Bhp-hr (g/kW-hr)	0.422(268)	0.442(280)	0.433(275)	4.8(3046)
<u>Temperatures, °F(°C)</u>				
Exhaust before turbocharger	954(512)	978(526)	964(518)	292(144)
Water Jacket Inlet	168(76)	172(78)	170(77)	99(37)
Water Jacket Outlet	180(82)	182(83)	180(82)	104(40)
Oil Sump	229(109)	234(112)	232(111)	129(54)
Fuel In	91(33)	96(36)	93(34)	84(29)
Inlet Air	80(27)	92(33)	87(31)	81(27)
Intake Manifold	220(104)	238(114)	229(109)	85(29)
<u>Pressures</u>				
Intake Vacuum, in. H ₂ O (Pa)	2.6(650)	2.7(670)	2.7(670)	0.1(20)
Exhaust Common, in. Hg (kPa)	0.7(2.4)	0.9(3.1)	0.8(2.7)	0.0(0.0)
Intake Manifold, psi (kPa)	9.6(66.1)	10.2(70.3)	9.9(68.2)	0.0(0.0)
Exhaust Manifold, psi (kPa)	12.5(86.1)	13.0(89.6)	12.8(88.2)	1.0(6.9)
Fuel Transfer Pump, psi (kPa)	69(475)	70(482)	70(482)	38(262)
Oil Gallery, psi (kPa)	64(441)	68(469)	67(462)	76(524)
Blowby, in. H ₂ O (Pa)	0.6(140)	1.2(290)	0.8(200)	0.1(30)
<u>Ambient Conditions</u>				
Wet Bulb Temperature, °F(°C)			67(19)	
Dry Bulb Temperature, °F(°C)			75(24)	
Barometric Pressure, in. Hg (kPa)			29.08(98.6)	

LDT-465 210 HOUR WHEELED VEHICLE CYCLE

BEFORE AND AFTER TEST 4 PERFORMANCE DATA



LDT-465-1C
TEST 4
LUBRICANT ANALYSIS
Lubricant: AL-8980-L

	ASTM Test Method	0	70	140	210
Apparent Viscosity at -29°C(-20°F), cP	D 2602	>26500	>26500	>26500	>26500*
Apparent Viscosity at -18°C(0°F), cP	D 2602	>9670	>9670	>9670	>9670 *
Kinematic Viscosity at 40°C(104°F), cSt	D 445	110	199	292	297
Kinematic Viscosity at 100°C(212°F), cSt	D 445	11.6	17.7	22.4	23.2
Viscosity Index	D 2270	92	96	94	97
Total Acid Number, mg KOH/g	D 664	5.4	4.8	5.7	6.0
Total Base Number, mg KOH/g	D 664	13.1	5.4	5.1	5.5
Pentane B Insolubles, wt%	D 893	0.02	2.80	5.62	6.71
Toluene B Insolubles, wt%	D893	0.02	2.16	4.74	5.31
Flash Point, °C(°F)	D 92	214(417)	204(399)	222(432)	214(417)
Density at 16°C(60°F), g/ml	D 287	0.90	0.93	0.94	0.94
Carbon Residue, wt%	D 524	1.5	4.5	6.3	7.1
Sulfated Ash, wt%	D 874	1.8	2.4	3.2	3.6

*The reason for unchanging viscosities with time is that the lubricant viscosity, at all test times, exceeded the limits of the viscosity standards currently available.

LDT-465-1C
TEST 4
TOTAL OIL CONSUMPTION AND WEAR METALS
Lubricant: AL-8980-L

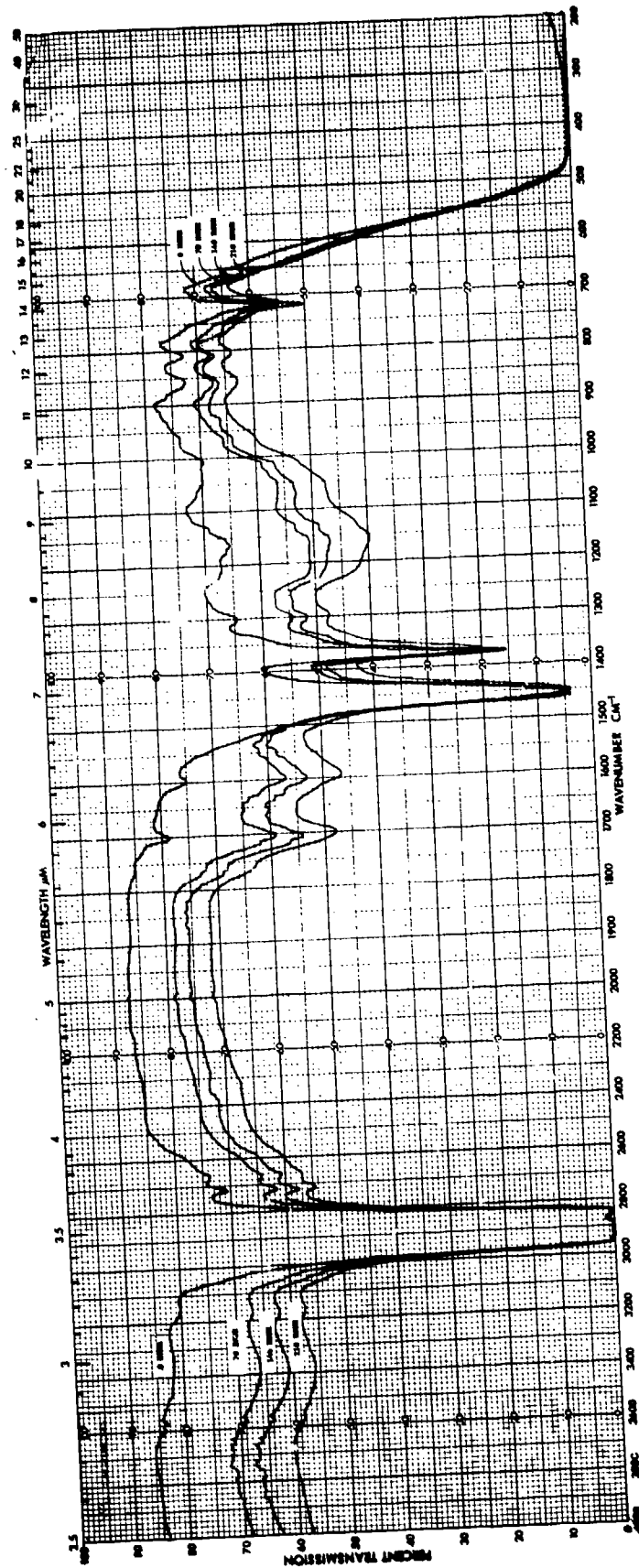
<u>Test Time, Hours</u>	<u>Total Oil Consumed, lb(kg)</u>	<u>Wear Metals⁺, ppm</u>	
		<u>Fe (Iron)</u>	<u>Cu (Copper)</u>
14	6.8(3.1)	25	---*
28	19.0(8.6)	24	---
42	27.4(12.4)	34	19
56	38.2(17.3)	41	---
70	49.2(22.3)	52	---
84	59.2(26.9)	53	---
98	71.6(32.5)	62	---
112	79.2(35.9)	62	---
126	87.9(39.9)	74	13
140	99.6(45.2)	93	---
154	111.1(50.4)	84	10
168	123.9(56.2)	87	10
182	134.6(61.1)	98	8
196	145.4(66.0)	98	10
210	155.8(70.7)	108	---

Average Oil Consumption Rate: 0.74 lb/hr (0.34kg/hr)

+ No other wear metals detected.

* --- = Not Detected.

LDT-465-1C
 TEST 4
 Lubricant: AL-8980-L



LDT-465-1C
TEST 4
WEAR MEASUREMENTS
Lubricant: AL-8980-L

Cylinder Liner Bore Diameter, inches

	Before Test			After Test			Change		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
1 T-AT	4.5639	4.5642	4.5644	4.5650	4.5652	4.5653	0.0011	0.0010	0.0009
F-B	4.5629	4.5629	4.5629	4.5633	4.5630	4.5632	0.0004	0.0001	0.0003
2 T-AT	4.5692	4.5638	4.5636	4.5646	4.5642	4.5639	0.0004	0.0004	0.0003
F-B	4.5632	4.5634	4.5638	4.5637	4.5638	4.5640	0.0005	0.0004	0.0002
3 T-AT	4.5635	4.5636	4.5635	4.5642	4.5641	4.5641	0.0007	0.0005	0.0006
F-B	4.5625	4.5623	4.5625	4.5632	4.5617	4.5628	0.0007	-0.0006	0.0003
4 T-AT	4.5640	4.5641	4.5640	4.5645	4.5644	4.5643	0.0005	0.0003	0.0003
F-B	4.5622	4.5625	4.5632	4.5631	4.5633	4.5636	0.0011	0.0008	0.0004
5 T-AT	4.5635	4.5637	4.5638	4.5643	4.5642	4.5639	0.0008	0.0005	0.0001
F-B	4.5621	4.5623	4.5626	4.5631	4.5630	4.5632	0.0010	0.0007	0.0007
6 T-AT	4.5633	4.5640	4.5641	4.5644	4.5646	4.5645	0.0011	0.0006	0.0007
F-B	4.5628	4.5633	4.5637	4.5634	4.5636	4.5639	0.0006	0.0002	0.0002

Average Change, in.: +0.0005

LDT-465-1C
TEST 4
WEAR MEASUREMENTS
Lubricant: AL-8980-L

Piston Ring End Gap, inches

<u>Piston No.</u>	<u>Ring No.</u>	<u>Before Test End Gap</u>	<u>After Test End Gap</u>	<u>Change</u>
1	1	0.022	0.024	0.002
	2	0.021	0.024	0.003
	3	0.018	0.020	0.002
	4	0.020	0.024	0.004
2	1	0.022	0.025	0.003
	2	0.021	0.024	0.003
	3	0.019	0.020	0.001
	4	0.018	0.020	0.002
3	1	0.024	0.027	0.003
	2	0.023	0.024	0.001
	3	0.021	0.023	0.002
	4	0.022	Broke	---
4	1	0.023	0.025	0.002
	2	0.025	0.028	0.003
	3	0.020	0.022	0.002
	4	0.021	0.026	0.005
5	1	0.024	0.027	0.003
	2	0.023	0.025	0.002
	3	0.020	0.021	0.001
	4	0.022	0.024	0.002
6	1	0.023	0.025	0.002
	2	0.023	0.024	0.001
	3	0.020	0.021	0.001
	4	0.019	0.020	0.001

Average Change, in.: +0.002

POST TEST ENGINE CONDITION AND DEPOSITS

LDT-465-1C TEST 4

Engine SN: 3904343

Lubricant: AL-8980-L

Fuel: Cat 1-H

Date Started: 19 Dec 1979

Date Completed: 14 Jan 1980

Test: 210 Hour Wheeled Vehicle Cycle

A. CYLINDER RATINGS

		Cylinder Number					
		1		2		3	
Deposits		Carb	Lacq	Carb	Lacq	Carb	Lacq
Cylinder Head		10% AHC*	0	5% AHC	0	10% AHC	0
		90% Soot		95% Soot		95% Soot	
Cylinders	ART**	15% 1/2 AHC 10% 1/2 AHC	10% 5 ⁺	15% 1/2 AHC 5% 1/2 AHC	5% 5 5% 9	15% 1/2 AHC	5% 5 5% 7 5% 9
	RTA	0	0	0	0	0	0
	BRT ¹	0	100% 7	0	100% 7	0	100% 7

		Cylinder Numbers					
		4		5		6	
Deposits		Carb	Lacq	Carb	Lacq	Carb	Lacq
Cylinder Head		10% AHC	0	5% AHC	0	5% AHC	0
		90% Soot		95% Soot		95% Soot	
Cylinders	ART**	10% 1/2 AHC 20% 1/2 AHC	5% 5 5% 7 5% 8	10% 1/2 AHC 20% 1/2 AHC	5% 4 5% 9	15% 1/2 AHC 5% 1/2 AHC	5% 8
	RTA	0	0	0	0	0	0
	BRT ¹	0	100% 7	0	100% 7	0	100% 7

Surface Condition		1	2	3
Cylinders	RTA	5% G, LS ⁺⁺	LS	LS
	BRT	N	N	N
Surface Condition		4	5	6
Cylinders	RTA	5% G, LS	LS	LS
	BRT	N	N	N

* HC = Hard carbon, and the number-letter prefix indicates carbon depth with
1/2 A = least, through the alphabet to J = most.

** ART = Above ring travel, RTA = Ring travel area, BRT = Below ring travel.

+ The higher the number, the darker the lacquer (0 = lightest, 9 = darkest).

++ V = Very, L = Light, H = Heavy, G = Glazing, P = Pitting, W = Wiping,
F = Flaking, S = Scratched, T = Thrust side, AT = Anti-thrust side.

¹ Accurate evaluation difficult due to the metal treatment given new cylinders.

B. PISTON RATINGS

Ring Face Condition	Cylinder Number					
	1	2	3	4	5	6
No. 1	N ^a	N	N	N	N	N
No. 2	N	N	N	N	N	N
No. 3	N	N	N	N	N	N
No. 4 (oil control)	N	N	- ^c	N	N	N
Oil Ring Slots, % Open	100	100	100	100	100	100

Ring Deposits

Piston Deposits		Cylinder Number					
		1		2		3	
		Carb	Lacq	Carb	Lacq	Carb	Lacq
Top	1	0	1% 5	0	1% 8	0	0
	2	0	0	0	1% 3	0	10% 3
	3	0	80% 5 20% 7	0	100% 7	0	75% 5 25% 7
ID	1	0	30% 3 55% 6 15% 8	50% AHC	15% 3 35% 9	45% AHC	35% 4 20% 9
	2	100% AHC	0	70% AHC 30% 1/2 AHC	0	25% 1/2 AHC	75% 9
	3	0	100% 9	0	100% 9	0	100% 9
Bottom	1	0	0	0	0	0	0
	2	0	5% 3	0	10% 3	0	5% 3
	3	0	100% 7	0	85% 6 15% 7	0	65% 5 35% 7

Piston Deposits		Cylinder Number					
		4		5		6	
		Carb	Lacq	Carb	Lacq	Carb	Lacq
Top	1	0	15% 5 2% 9	0	0	0	1% 5
	2	0	10% 4	0	0	0	0
	3	0	85% 5 15% 7	0	50% 4 50% 6	0	100% 6
ID	1	10% 1/2 AHC 40% 1/2 AHC	50% 5	0	25% 3 15% 6 15% 7 45% 9	0	35% 4 65% 9
	2	40% 1/2 AHC	60% 9	100% 1/2 AHC	0	100% 1/2 AHC	0
	3	0	100% 9	0	100% 9	0	100% 9
Bottom	1	0	10% 5	0	0	0	0
	2	0	0	0	20% 3	0	0
	3	0	95% 6 5% 7	0	80% 4 20% 6	0	85% 4 15% 7

^aN = Normal condition, no scuffing

^bsc = Scuffed

^c- = Ring broke while removing

Piston Surface Condition

	Piston Number					
	1	2	3	4	5	6
Top Ring Land	N	N	N	N	N	N
Skirt	N, LS	N, LS	N, LS	N, LS	N, LS	N, LS
Piston Pin	N	N	N	N	N	N

CRC Diesel Engine Piston Rating

	Piston Number					
	1	2	3	4	5	6
WTD ^d rating	289	195	288	312	316	241
Av. WTD rating: 274						

C. VALVE RATINGS

	Cylinder Number											
	1		2		3		4		5		6	
	INT	EXH	INT	EXH	INT	EXH	INT	EXH	INT	EXH	INT	EXH
Freeness in Guide	F ^e	F	F	S ^f	F	S	F	S	F	S	F	F
Head	-	-	-	-	-	-	-	-	-	-	-	-
Face	-	-	-	-	-	-	-	-	-	-	-	-
Seat	-	-	-	-	-	-	-	-	-	-	-	-
Stem	N	LG ^g	N	LG	N	LG	N	LG	N	LG	N	LG
Tip	-	-	-	-	-	-	-	-	-	-	-	-

D. OTHER RATINGS

Bearing Surface Condition - All normal

^dWTD = Weighted Total Deposits, 0 = Clean, 900 = maximum possible deposits

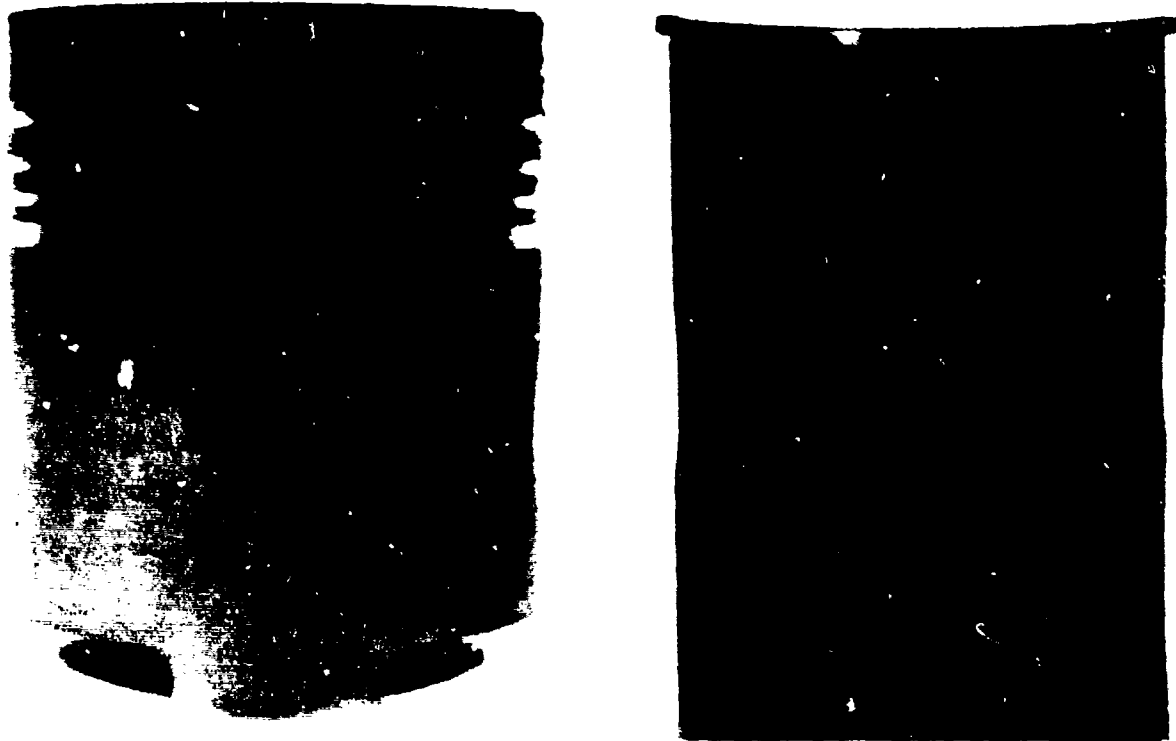
^eF = Free

^fS = Stuck (The stuck valves came loose with a light tap)

^gLG = Light Gauling

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

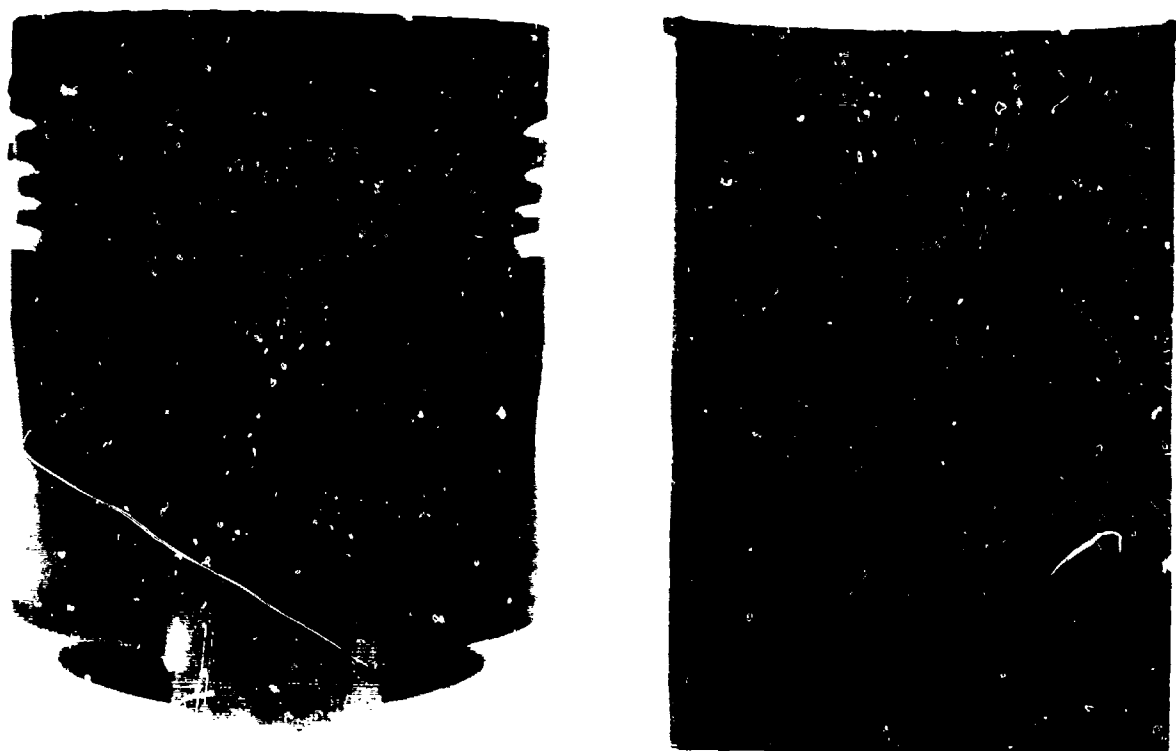
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



1-Thrust

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



1 Anti-Thrust

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER

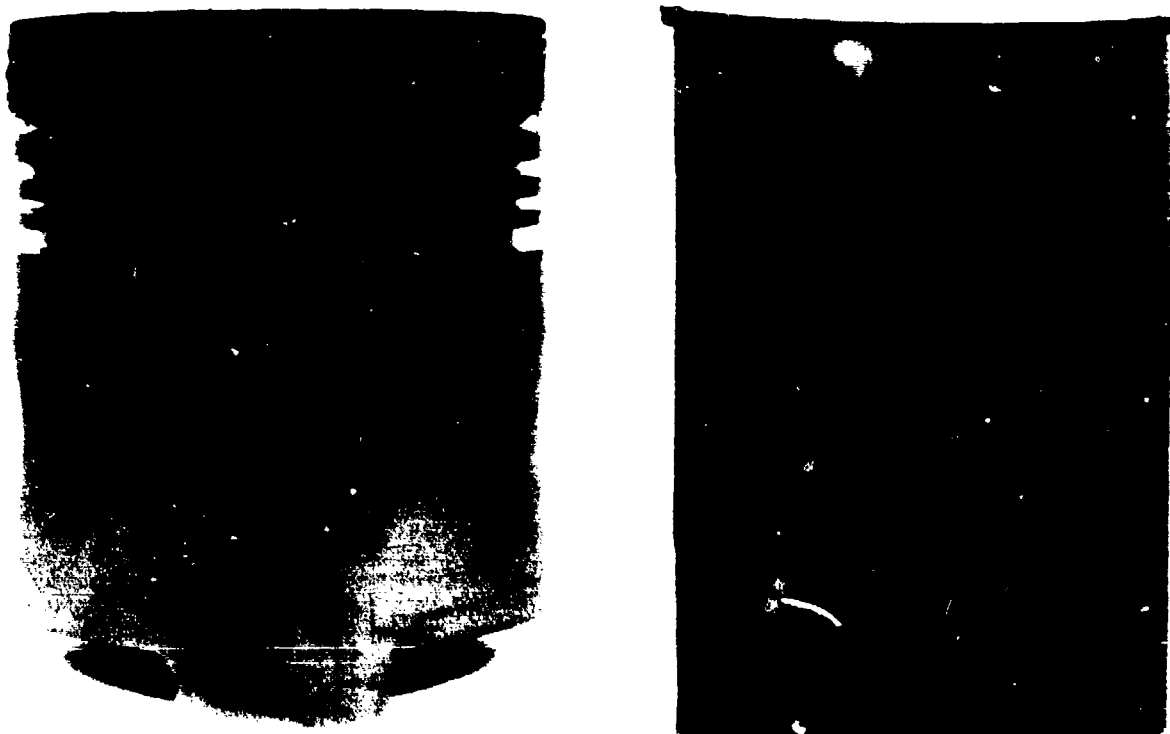


2 Thrust*

* No. 2 Piston had the lowest Weighted Total Deposit (WTD) rating.

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER

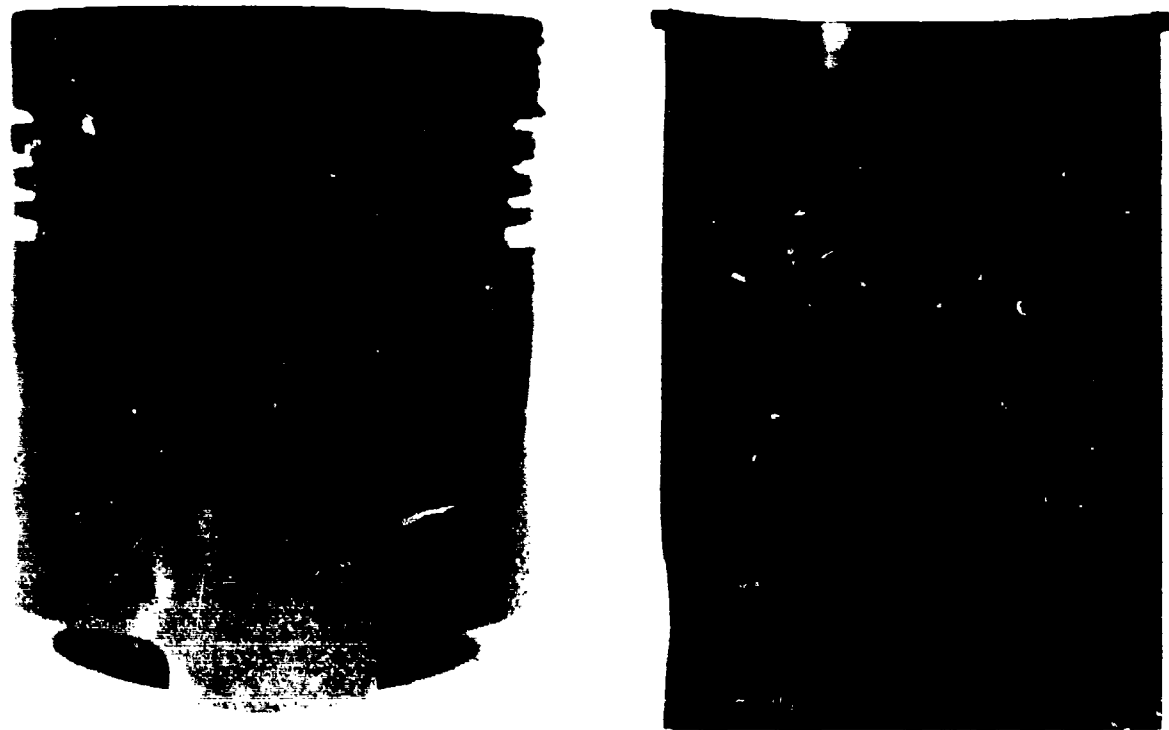


2 Anti-Thrust*

* No. 2 Piston had the lowest Weighted Total Deposit (WTD) rating.

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

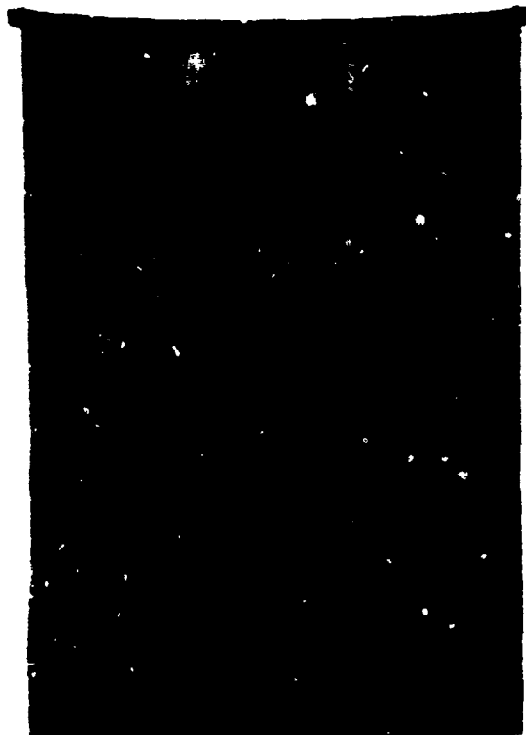
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



3 Thrust

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



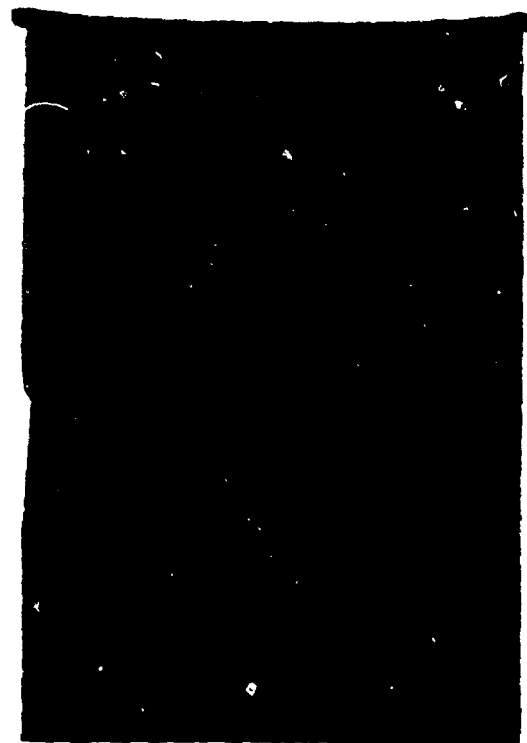
3 Anti-Thrust

LDT-465-1C

TEST 4

Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



4 Thrust

K-21

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



4 Anti-Thrust

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER

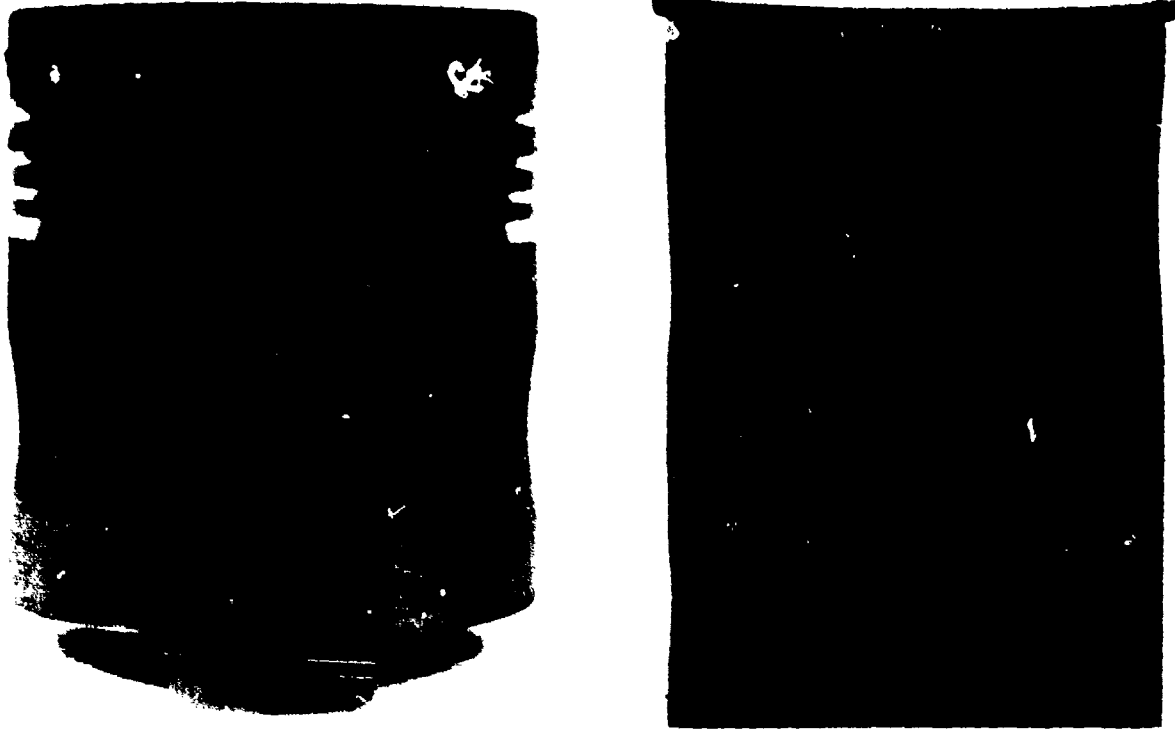


5 Thrust*

* No. 5 Piston had the highest Weighted Total Deposits (WTD) rating.

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



5 Anti-Thrust*

* No. 5 Piston had the highest Weighted Total Deposits (WTD) rating.

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



6 Thrust

K-25

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

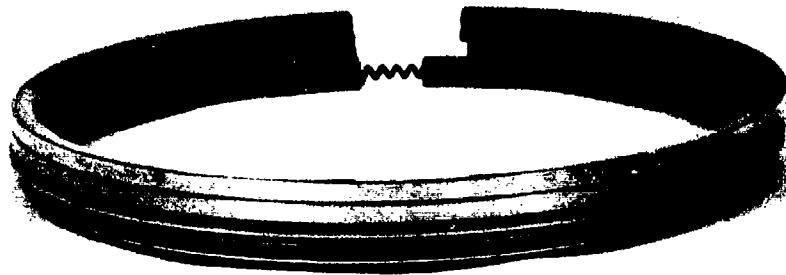
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



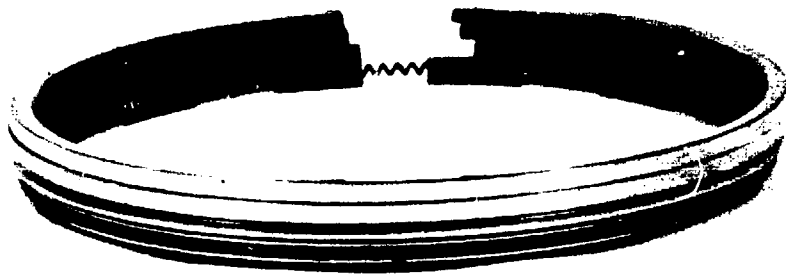
6 Anti-Thrust

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON RINGS



No. 1



No. 2



No. 3

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF PISTON RINGS



No. 4
(largest increase in end gap)



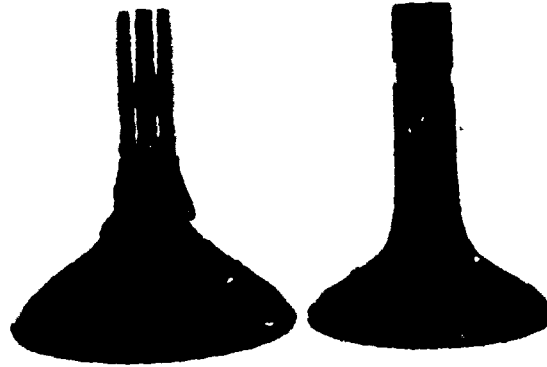
No. 5



No. 6
(least increase in end gap)

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

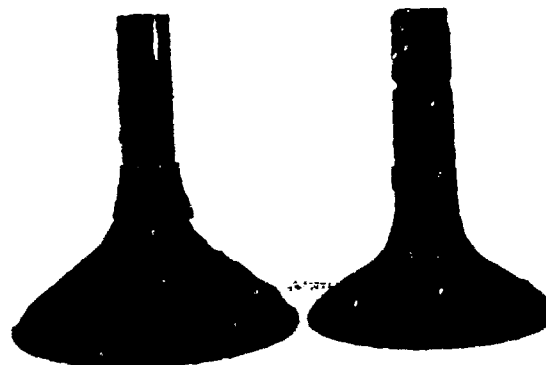
AFTER TEST CONDITION OF INTAKE AND EXHAUST VALVES



No. 1



No. 2
(lowest valve deposit rating)

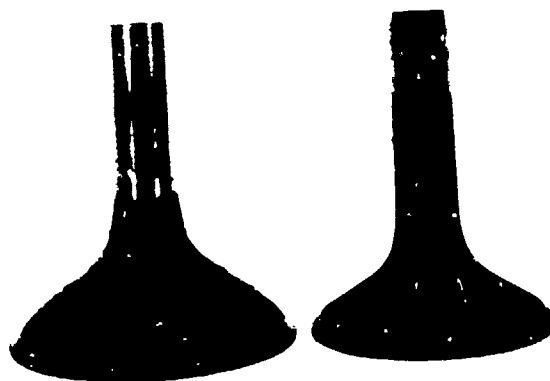


No. 3

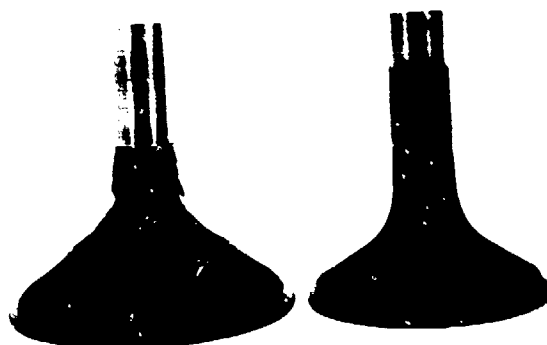
K-29

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

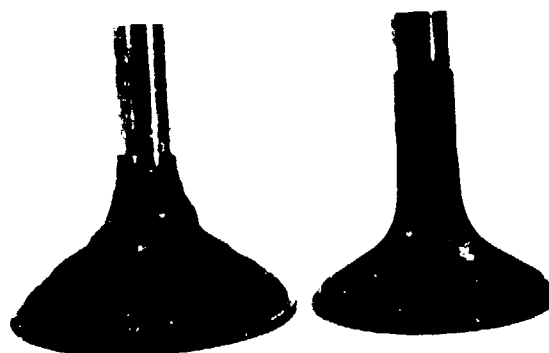
AFTER TEST CONDITION OF INTAKE AND EXHAUST VALVES



No. 4



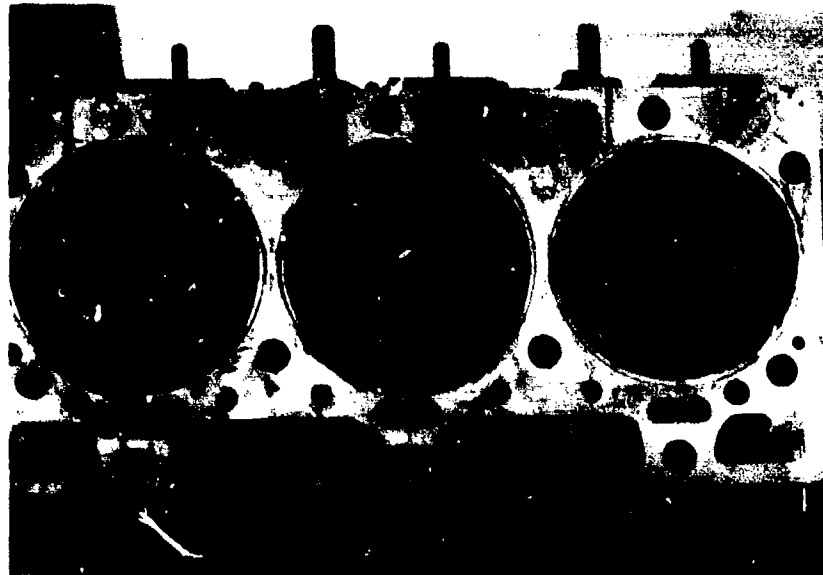
No. 5



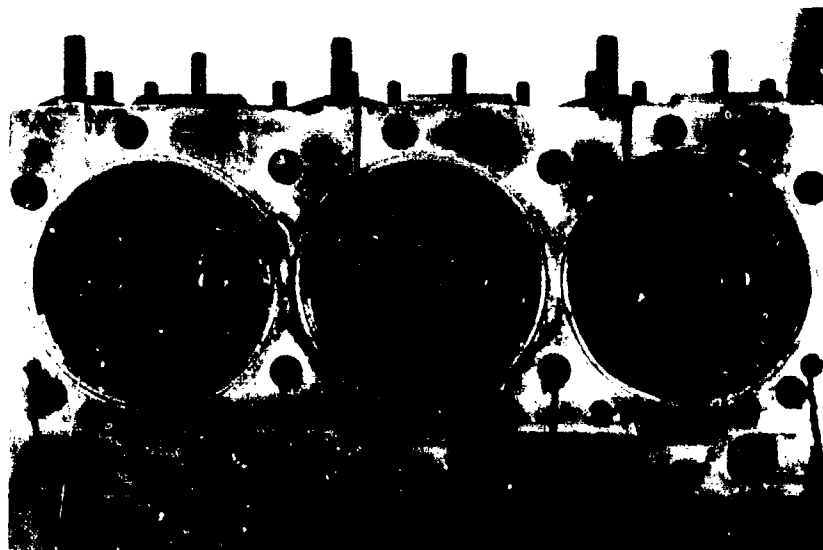
No. 6
(highest valve deposit rating)

LDT-465-1C
TEST 4
Lubricant: AL-8980-L

AFTER TEST CONDITION OF CYLINDER HEADS



Cylinders 3, 2, 1



Cylinders 6, 5, 4

APPENDIX L

ENGINE-LUBRICANT COMPATIBILITY TEST #5
210-HOUR WHEELED-VEHICLE CYCLE
USING LDT-465-1C DIESEL ENGINE

**ENGINE-LUBRICANT COMPATIBILITY TEST
210-HOUR WHEELED-VEHICLE CYCLE
USING LDT-465-1C DIESEL ENGINE**

**Test Lubricant: AL-8924-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 5
Date Completed: 27 February 1980**

Conducted for

**U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia**

by

**U.S. Army Fuels & Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284**

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LDT-465-1C
TEST 5
ENGINE REBUILD MEASUREMENTS

	Inches			
<u>Cylinder Liners (Installed)</u>	<u>Min.</u>	<u>Max</u>	<u>Avg.</u>	<u>Specified Limits</u>
Inside Diameter	4.5630	4.5646	4.5639	4.5630 - 4.5645
Out of Round	0.0001	0.0012	0.0006	0.0015 Max
Taper	0.0001	0.0006	0.0004	0.0015 Max
Piston Skirt Diameter (@ bottom)	4.5552	4.5558	4.5555	4.5530 - 4.5580
<u>No. 1 Ring</u>				
End Gap	0.022	0.027	0.024	0.022 - 0.035
<u>No. 2 Ring</u>				
End Gap	0.023	0.027	0.024	0.022 - 0.035
<u>No. 3 Ring</u>				
End Gap	0.020	0.027	0.023	0.022 - 0.035
Side Clearance	0.0030	0.0040	0.0033	0.0025 - 0.0045
<u>No. 4 Ring</u>				
End Gap	0.018	0.026	0.020	0.010 - 0.028
Side Clearance	0.0015	0.0020	0.0016	0.0010 - 0.0035

**LDT-465-1C 210-HOUR WHEELED VEHICLE CYCLE ENDURANCE TEST
TEST 5**

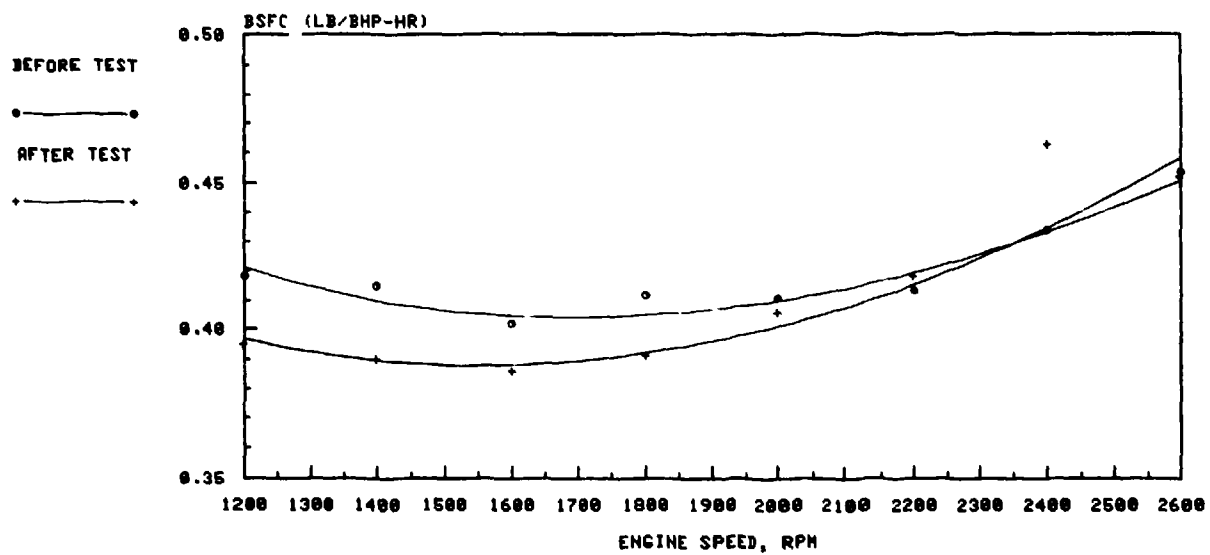
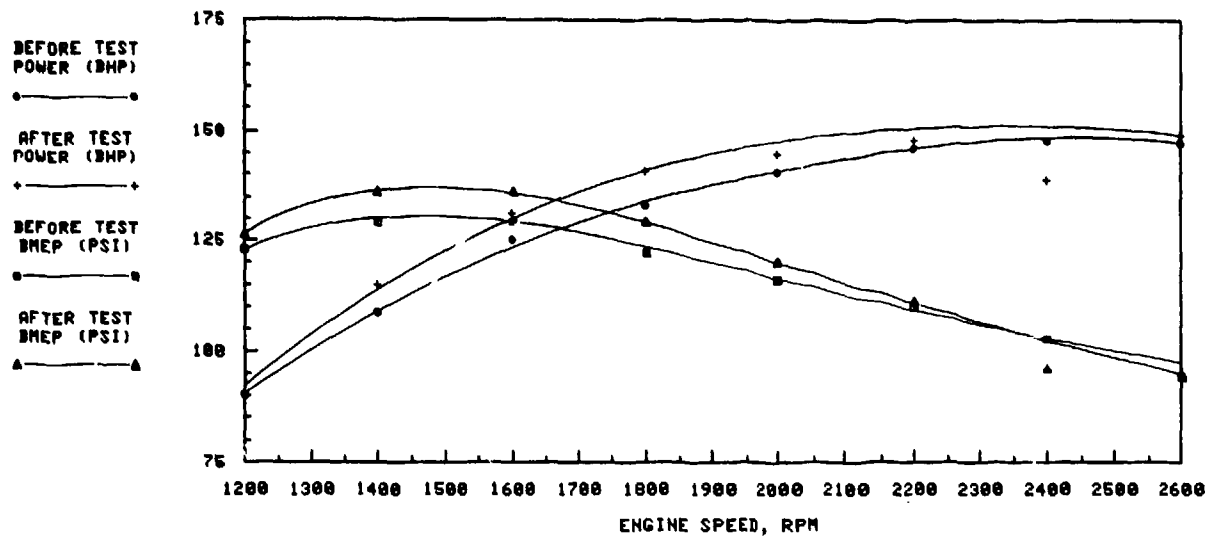
OPERATING CONDITIONS SUMMARY

Fuel: AL-8764-F

Lubricant: AL-8924-L

	<u>Power Mode</u>			<u>Idle Mode</u>
	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Avg</u>
Engine Speed, RPM	2602	2607	2605	811
Torque, Ft-lb, (N-m)	298(404)	316(428)	307(416)	18(24)
Observed Power, Bhp(kW)	148(110)	156(116)	152(113)	2.7(2.0)
Fuel Consumption, lb/hr (kg/hr)	66.6(30.2)	68.0(30.9)	67.1(30.5)	4.9(2.2)
BSFC, lb/Bhp-hr (g/kW-hr)	0.43(273)	0.46(292)	0.44(279)	1.9(1206)
<u>Temperatures, °F(°C)</u>				
Exhaust Manifold	1004(540)	1075(579)	1049(565)	237(114)
Water Jacket Inlet	166(74)	169(76)	168(76)	95(35)
Water Jacket Outlet	177(81)	181(83)	180(82)	100(38)
Oil Sump	221(105)	227(108)	224(107)	118(48)
Fuel In	83(28)	90(32)	88(31)	73(23)
Inlet Air	69(21)	88(31)	79(26)	67(19)
Intake Manifold	227(108)	242(117)	234(112)	69(21)
<u>Pressures</u>				
Intake Vacuum, in. H ₂ O(Pa)	2.9(720)	2.9(720)	2.9(720)	0.1(20)
Exhaust Common, in. Hg(kPa)	0.8(2.7)	0.9(3.1)	0.9(3.1)	0.0(0.0)
Intake Manifold, psi (kPa)	10.6(73.0)	11.1(76.5)	10.7(73.7)	0.0(0.0)
Exhaust Manifold, psi (kPa)	12.0(82.7)	13.4(92.3)	13.0(89.6)	0.0(0.0)
Fuel Transfer Pump, psi (kPa)	73(503)	73(503)	73(503)	39(269)
Oil Gallery, psi (kPa)	59(407)	62(427)	61(420)	65(448)
Blowby, in. H ₂ O(Pa)	1.6(400)	2.2(550)	2.0(500)	0.2(50)
<u>Ambient Conditions</u>				
Wet Bulb Temperature, °F(°C)			67(19)	
Dry Bulb Temperature, °F(°C)			75(24)	
Barometric Pressure, in. Hg(kPa)			29.18(98.9)	

LDT-465 210 HOUR WHEELED VEHICLE CYCLE BEFORE AND AFTER TEST 5 PERFORMANCE DATA



LDT-465-1C
TEST 5
LUBRICANT ANALYSIS

LUBRICANT: AL-8924-L

	ASTM Test Method	Test Hour			
		0	70	140	210
Apparent Viscosity at -29°C(-20°F), cP	D 2602	3480	4200	4650	5300
Apparent Viscosity at -18°C(0°F), cP	D 2602	1180	1300	1530	1750
Kinematic Viscosity at 40°C(104°F), cSt	D 445	56.3	56.0	60.2	64.6
Kinematic Viscosity at 100°C(212°F), cSt	D 445	10.0	9.8	10.3	10.8
Viscosity Index	D 2270	165	162	160	158
Total Acid Number, mg KOH/g	D 664	2.4	3.9	3.6	4.4
Total Base Number, mg KOH/g	D 664	6.3	2.4	2.8	2.3
Pentane B Insolubles, wt%	D 893	—*	0.5	1.3	2.4
Toluene B Insolubles, wt%	D 893	—	0.5	1.2	2.1
Flash Point, °C(°F)	D 92	220(428)	220(428)	220(428)	220(428)
Density at 16°C(60°F), gm/ml	D 287	0.87	0.88	0.88	0.89
Carbon Residue, wt%	D 524	1.1	1.9	2.5	3.1
Sulfated Ash, wt%	D 874	1.0	1.2	1.5	1.8

*Not Determined

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

Total Oil Consumption and Wear Metals

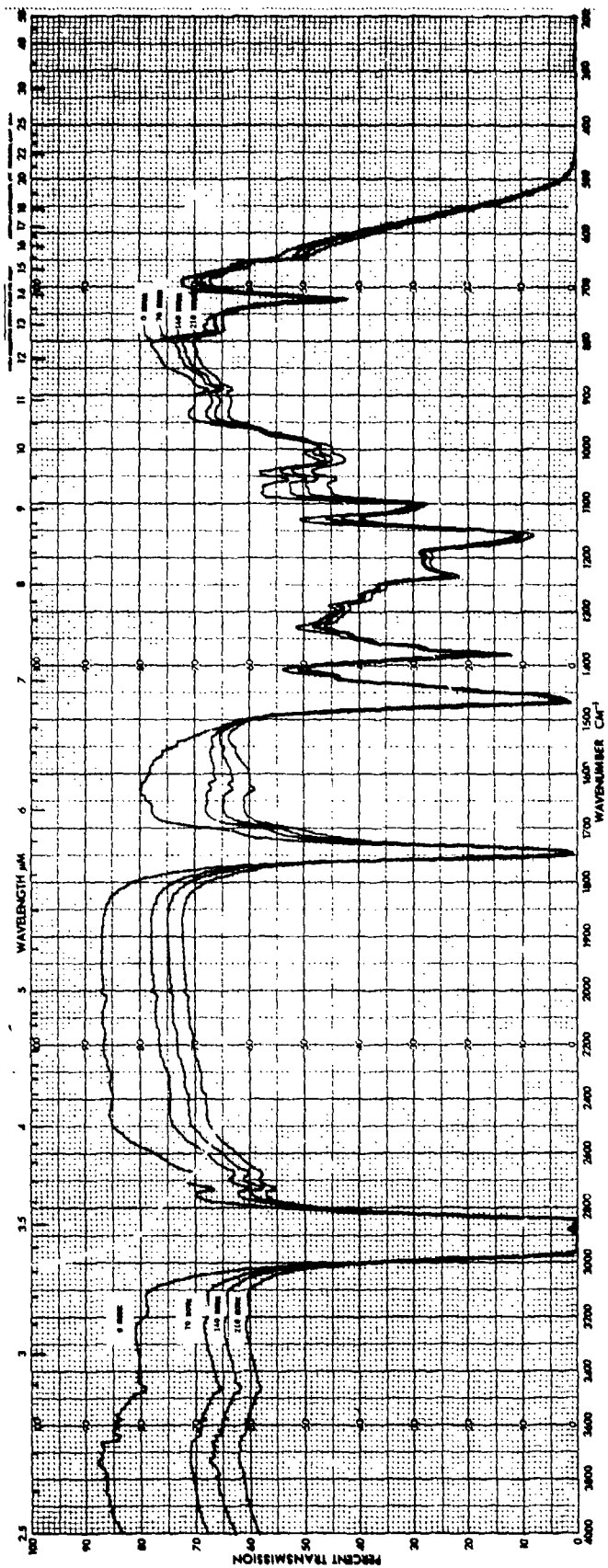
<u>Test Time, Hours</u>	<u>Total Oil Consumed, lb. (kg)</u>	<u>Wear Metals,* PPM</u>		
		<u>Fe</u>	<u>Cu</u>	<u>Cr</u>
14	1.4 (0.6)	44	-**	-
28	5.1 (2.3)	61	-	-
42	8.7 (4.0)	82	13	-
56	13.4 (6.1)	97	-	-
70	18.7 (8.5)	105	18	12
84	25.3 (11.5)	111	-	26
98	29.4 (13.3)	119	-	-
112	36.0 (16.3)	127	14	-
126	41.3 (18.7)	149	13	-
140	46.1 (20.9)	146	-	-
154	49.6 (22.5)	162	19	-
168	55.5 (25.2)	187	12	-
182	62.8 (28.5)	228	-	-
196	67.8 (30.7)	226	13	-
210	72.6 (32.9)	252	-	31

Average Oil Consumption Rate: 0.35 LB/HR (0.16 KG/HR).

* No Other Wear Metals Detected.

**Not Detected.

LDT-465-1C
TEST 5
Lubricant: AL-8924-L



LDT-465-1C

TEST 5

Lubricant: AL-8924-L

Wear Measurements

Cylinder Liner Bore Diameter, inches

	<u>Before Test</u>			<u>After Test</u>			<u>Change</u>		
	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>
1. T-AT	4.5638	4.5639	4.5641	4.5629	4.5633	4.5640	-0.0009	-0.0006	-0.0001
F-B	4.5634	4.5634	4.5639	4.5644	4.5641	4.5637	0.0010	0.0007	-0.0002
2. T-AT	4.5633	4.5636	4.5637	4.5632	4.5633	4.5636	-0.0001	-0.0003	-0.0001
F-B	4.5636	4.5635	4.5639	4.5628	4.5629	4.5636	-0.0008	-0.0006	-0.0003
3. T-AT	4.5645	4.5645	4.5644	4.5647	4.5644	4.5642	0.0002	-0.0001	-0.0002
F-B	4.5633	4.5638	4.5640	4.5629	4.5633	4.5636	-0.0004	-0.0005	-0.0004
4. T-AT	4.5640	4.5645	4.5645	4.5647	4.5647	4.5646	0.0007	0.0002	0.0001
F-B	4.5635	4.5638	4.5641	4.5635	4.5634	4.5637	0.0000	-0.0004	-0.0004
5. T-AT	4.5642	4.5645	4.5646	4.5644	4.5646	4.5646	0.0002	0.0001	0.0000
F-B	4.5630	4.5631	4.5635	4.5632	4.5631	4.5634	0.0002	0.0000	-0.0001
6. T-AT	4.5641	4.5638	4.5637	4.5646	4.5638	4.5637	0.0005	0.0000	0.0000
F-B	4.5637	4.5640	4.5641	4.5639	4.5637	4.5639	0.0002	-0.0003	-0.0002

Average Change, in.: -0.0001

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

Wear Measurements

Piston Ring End Gap, inches

<u>Piston No.</u>	<u>Ring No.</u>	<u>Before Test</u> <u>End Gap</u>	<u>After Test</u> <u>End Gap</u>	<u>Change</u>
1	1	0.022	0.023	0.001
	2	0.023	0.024	0.001
	3	0.022	0.023	0.001
	4	0.019	0.020	0.001
2	1	0.023	0.024	0.001
	2	0.022	0.023	0.001
	3	0.022	0.024	0.002
	4	0.018	0.023	0.005
3	1	0.027	0.029	0.002
	2	0.027	0.028	0.001
	3	0.002	0.023	0.001
	4	0.026	0.029	0.003
4	1	0.022	0.023	0.003
	2	0.024	0.025	0.001
	3	0.020	0.021	0.001
	4	0.018	0.024	0.006
5	1	0.025	0.026	0.001
	2	0.025	0.026	0.001
	3	0.022	0.023	0.001
	4	0.021	0.024	0.003
6	1	0.022	0.024	0.002
	2	0.023	0.025	0.002
	3	0.027	0.030	0.003
	4	0.016	0.026	0.010

Average Changes, in.: +0.002

POST TEST ENGINE CONDITION AND DEPOSITS

LDT-465-1C

Engine SN: 3904343

Lubricant: AL-8924-L

Fuel: Cat 1-H

Date Started: 7 February 1980

Date Completed: 27 February 1980

Test: 210 Hour Wheeled Vehicle Cycle

A. CYLINDER RATINGS

		Cylinder Number					
		1		2		3	
Deposits		Carb	Lacq	Carb	Lacq	Carb	Lacq
Cylinder Head		5% AHC*	0	100% 1/2 AHC	0	10% BHC 15% AHC 75% 1/2 AHC	0
Cylinders	ART**	10% AHC 15% 1/2 AHC	5% 9+	75% AHC	5% 9	75% AHC	0
	RTA	0	100% 8	0	100% 7	0	100% 7
	BRT ¹	0	0	0	0	0	0
		Cylinder Number					
		4		5		6	
Deposits		Carb	Lacq	Carb	Lacq	Carb	Lacq
Cylinder Head		10% AHC 90% 1/2 AHC	0	100% 1/2 AHC	0	10% AHC 90% 1/2 AHC	0
Cylinders	ART**	25% AHC	0	70% AHC	0	80% AHC	5% 9
	RTA	0	100% 8	0	100% 7	0	20% 5 80% 7
	BRT ¹	0	0	0	0	0	0
Surface Condition		1		2		3	
Cylinders	RTA	5% G, LS		LS		5% G, LS	
	BRT	VLS		LS		LS	
Surface Condition		4		5		6	
Cylinders	RTA	P to LS		LS		LS	
	BRT	LS		LS		LS	

¹ Accurate evaluation difficult due to the metal treatment given new cylinders.

* HC=Hard Carbon, and the number-letter prefix indicates carbon depth with 1/2 A=least, through the alphabet to J=most.

** ART=Above Ring Travel, RTA=Ring Travel Area, BRT=Below Ring Travel.

+ The higher the number, the darker the lacquer. (0=lightest, 9=darkest).

++ V=very, L=light, H=heavy, G=glazing, P=pitting, W=wiping, F=flaking, S=scratched, T=thrust side, AT=Anti thrust side

B. PISTON RATINGS

Ring Face Condition		Cylinder Number					
		1	2	3	4	5	6
No. 1		N ^a	N	N	N	<1% SC ^b	2% SC
No. 2		N	N	N	N	N	N
No. 3		N	N	N	N	N	N
No. 4 (Oil control)		N	N	N	N	N	N
Oil Ring Slots, % Open		100%	100%	100%	100%	100%	100%
Ring Deposits							
Piston Ring		Cylinder Number					
		1		2		3	
Top	1	Carb 0	Lacq 1% 9	Carb 0	Lacq 0	Carb 0	Lacq 3% 3 2% 9
	2	0	25% 2	0	45% 3 5% 7	5% 1/2 AHC	30% 3
	3	0	90% 7 10% 8	0	100% 7	0	100% 7
ID	1	0	25% 5 75% 9	85% AHC	15% 9	0	70% 3 30% 9
	2	0	100% 9	50% 1/2 AHC 0 50% AHC	0	100% 1/2 AHC	0
	3	0	100% 9	0	100% 9	0	100% 9
Bottom	1	0	0	0	5% 4	0	10% 3
	2	0	0	0	0	1% 1/2 AHC	50% 3
	3	0	50% 4 50% 7	0	25% 6	0	55% 6
Piston Ring		Cylinder Number					
		4		5		6	
Top	1	Carb 0	Lacq 0	Carb 0	Lacq 0	Carb 0	Lacq 1% 3
	2	0	15% 3	0	50% 3	0	65% 3
	3	0	100% 7	0	100% 6	0	60% 5 40% 6
ID	1	80% 1/2 AHC	20% 5	100% 1/2 AHC 0	0	100% AHC	0
	2	100% 1/2 AHC	0	50% 1/2 AHC 0 50% 1/2 AHC	0	100% 1/2 AHC	0
	3	0	100% 9	0	100% 9	0	100% 9
Bottom	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	35% 7	0	80% 6	0	50% 4

^aN=Normal condition,

^bSC=scuffed.

Piston Surface Condition

	Piston Number					
	1	2	3	4	5	6
Top Ring Land	N	N	N	N	N	N
Skirt	LST	N	N	N	N	N
Piston Pin	N	N	N	N	N	N

CRC Diesel Engine Piston Rating

	Piston Number					
	1	2	3	4	5	6
WTD ^c rating	199	198	166	184	162	151
Av. WTD rating:	177					

C. VALVE RATINGS

	Cylinder Number											
	1		2		3		4		5		6	
	INT	EXH	INT	EXH	INT	EXH	INT	EXH	INT	EXH	INT	EXH
Freeness in Guide	-----All Free-----											
Head	-----All Normal-----											
Face	-----All Normal-----											
Seat	-----All Normal-----											
Stem	-----All Normal-----											
Tip	-----All Normal-----											
Tulip Demerit Rating ^f	0.50	0.10	0.50	0.10	0.25	0.10	0.50	0.10	0.25	0.10	0.50	0.10

^cWTD = Weighted Total Deposits, 0 = Clean, 900 = Maximum possible deposits.

^dF = Free.

^f₁ = Least, 9 = Most (<1 = very clean).

D. OTHER RATINGS

Tappets, Cams, and Rocker Arms

	Cylinder Number					
	1	2	3	4	5	6
Tappet Deposit	All 1/2 A Sludge					
Rocker Arm Tip	Normal					
Bushing	Normal					
Shaft	Normal					

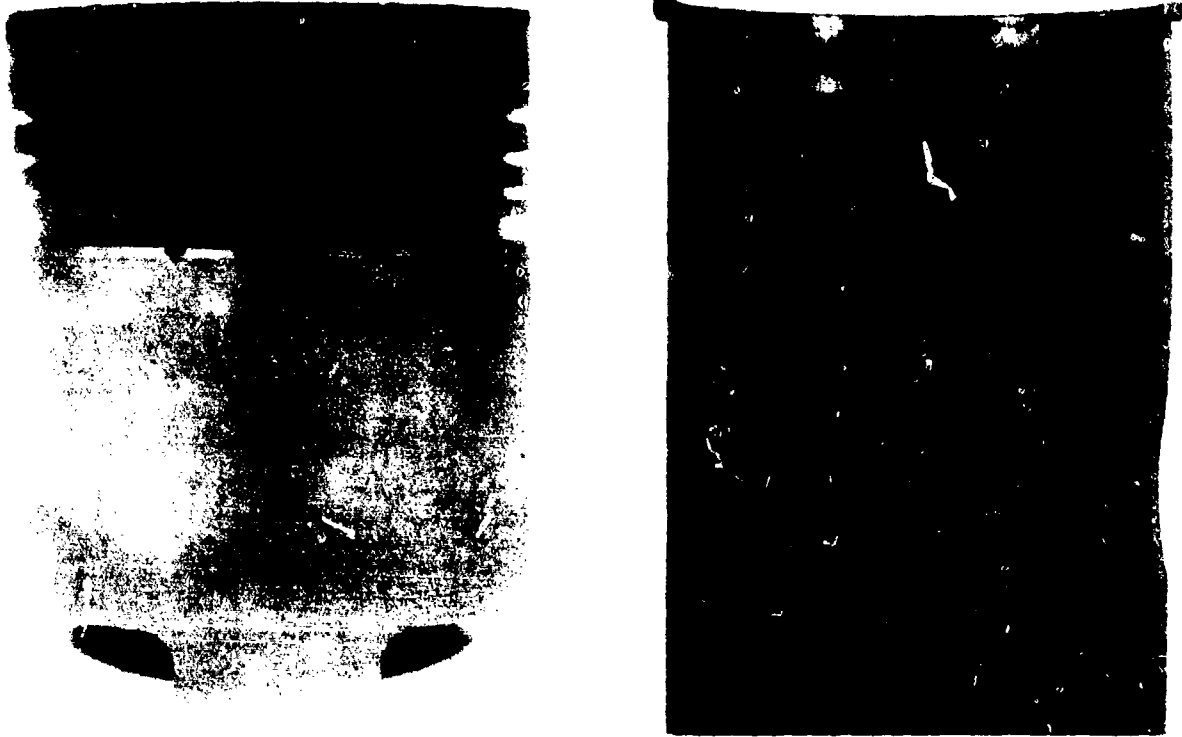
Bearing Surface Condition

	Bearing Number						
	1	2	3	4	5	6	7
Main Bearing	S	NR ^e	S	NR			
Main Journal	N	NR	N	NR			
Rod Bearing	N	LS, W	N	S, P, F	W, S	S	
Rod Journal	Normal						
Piston Pin	Normal						
Pin Bushing	Normal						

^eNR = Not Rated.

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



1 THRUST*

* Piston 1 had the highest weighted total deposit (WTD) rating

LDT-465-1C

TEST 5

Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



1 Anti-thrust*

* Piston 1 had the highest weighted total deposit (WTD) rating

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



2 Thrust

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

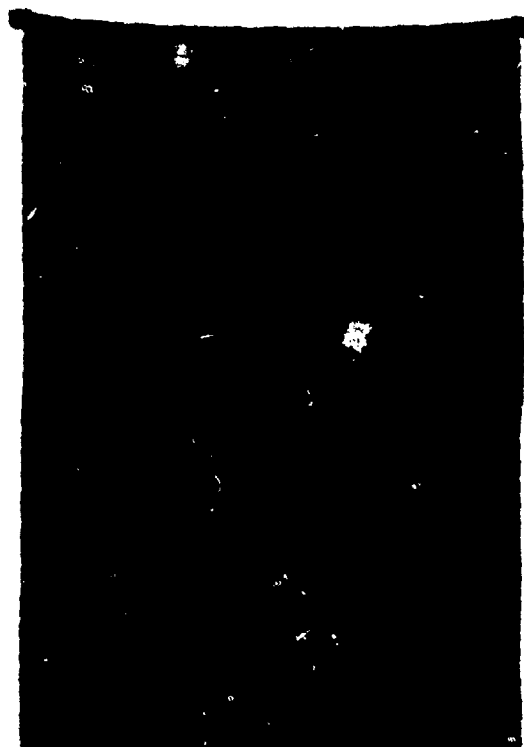
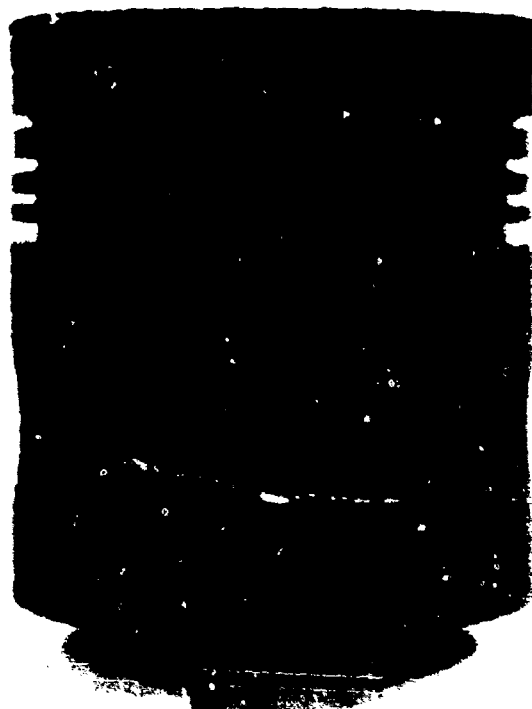
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



2 Anti-thrust

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



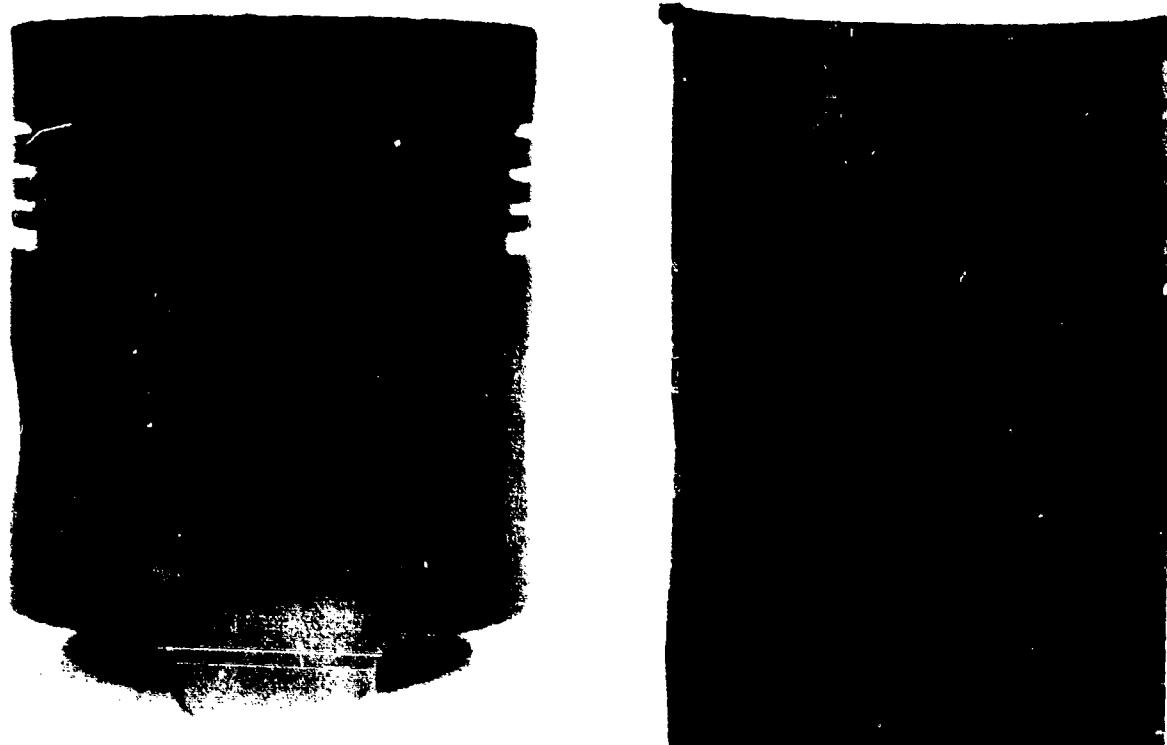
3 Thrust

L-20

LDT-465-1C
TEST 5

Lubricant: AL-8924-L

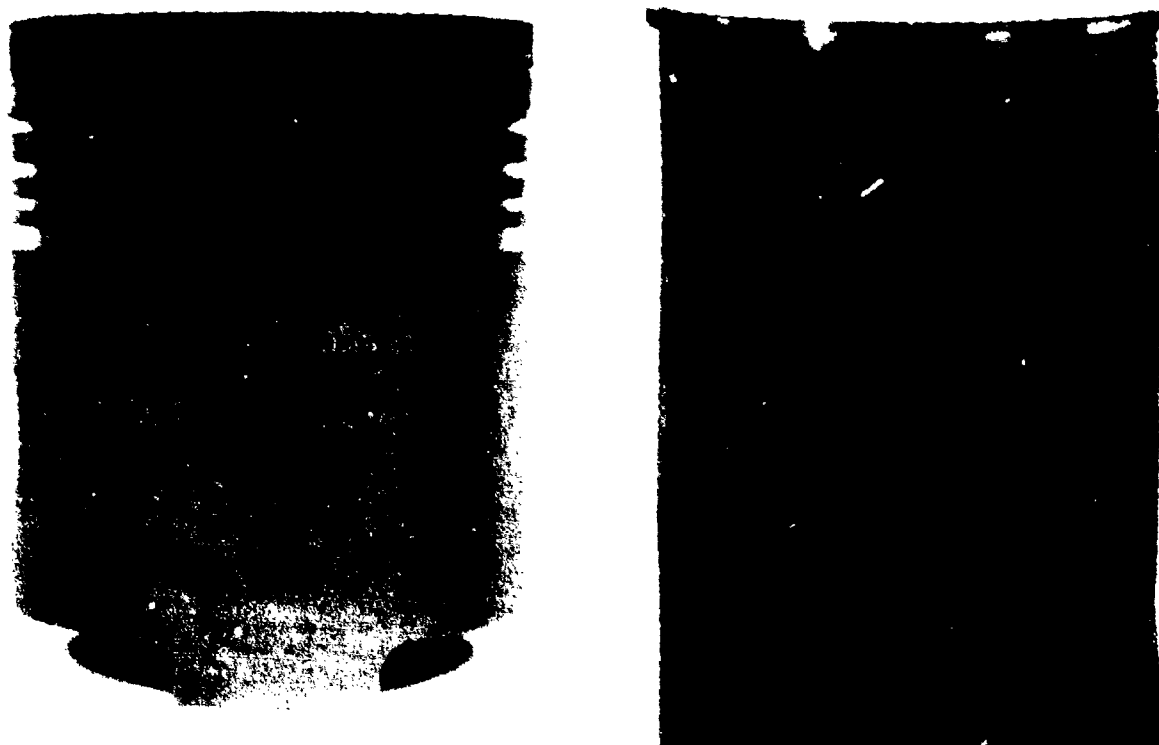
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



3 Anti-thrust

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



4 Thrust

L-22

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



4 Anti-thrust

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

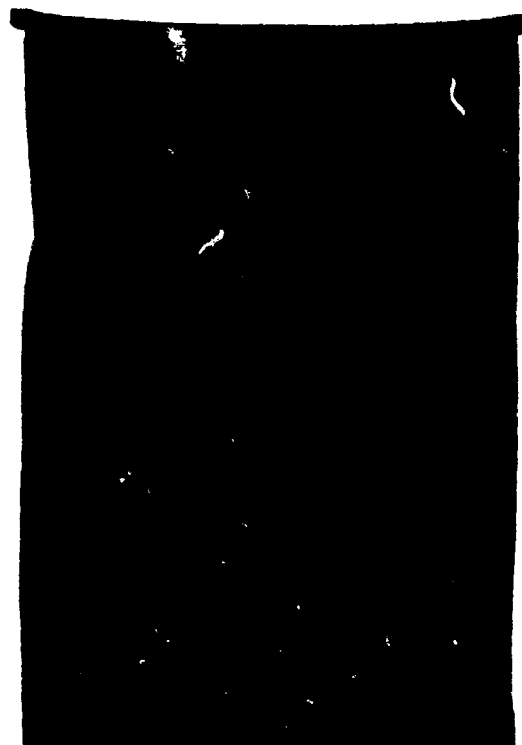
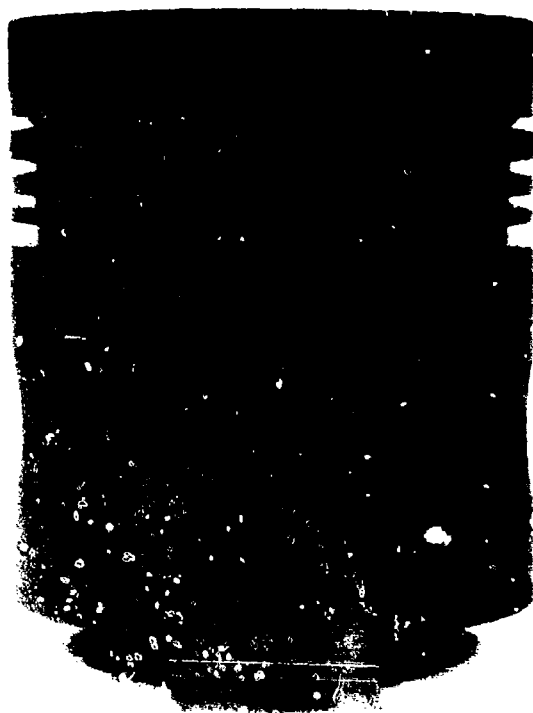
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



5 Thrust

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

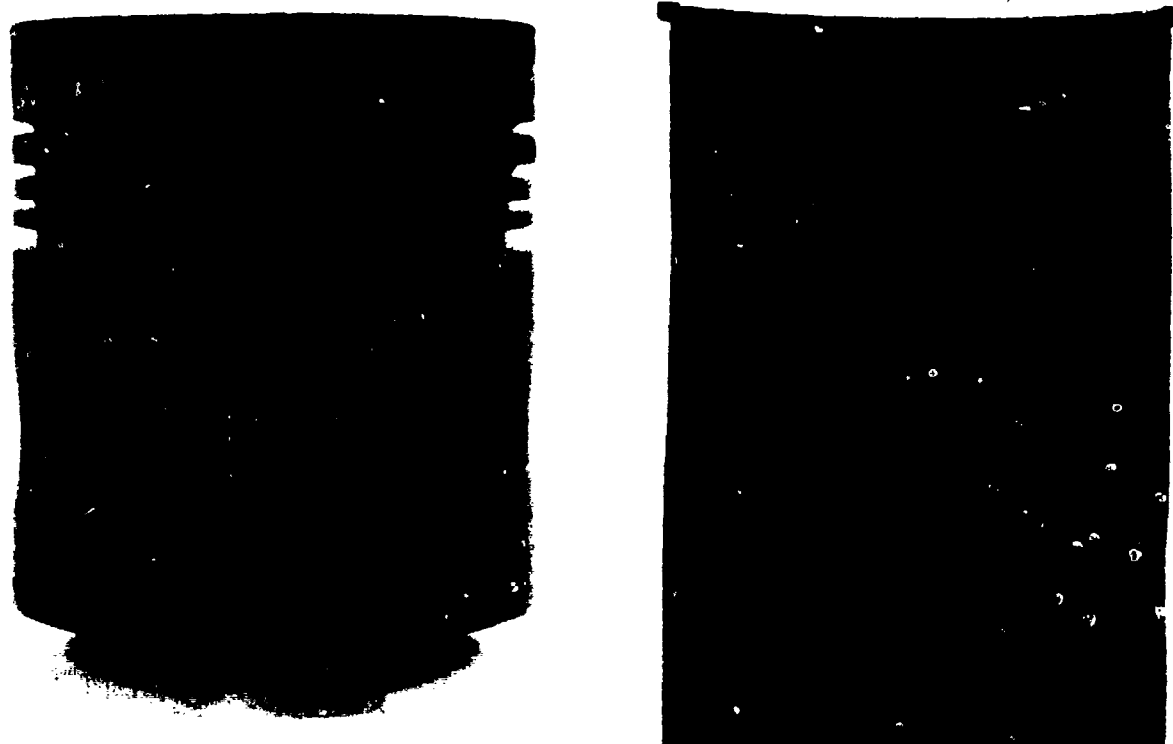
AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



5 Anti-thrust

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER

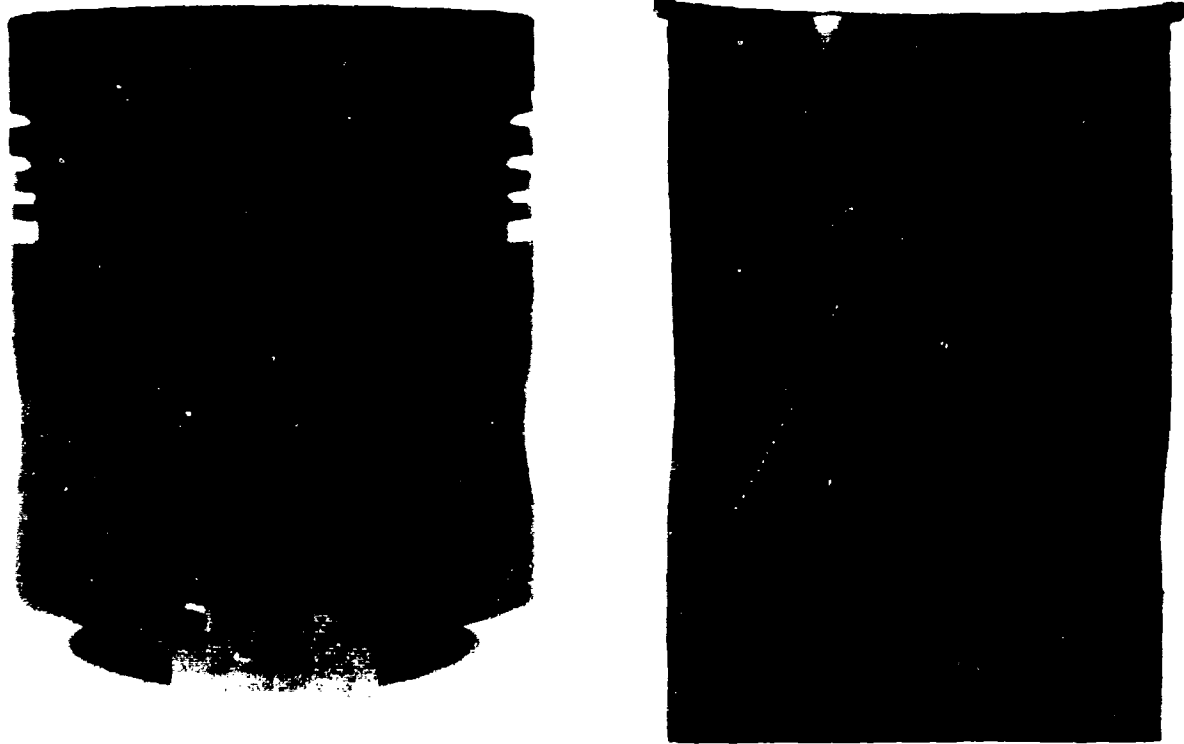


6 Thrust*

* Piston 6 had the lowest WTD rating.

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



6 Anti-thrust*

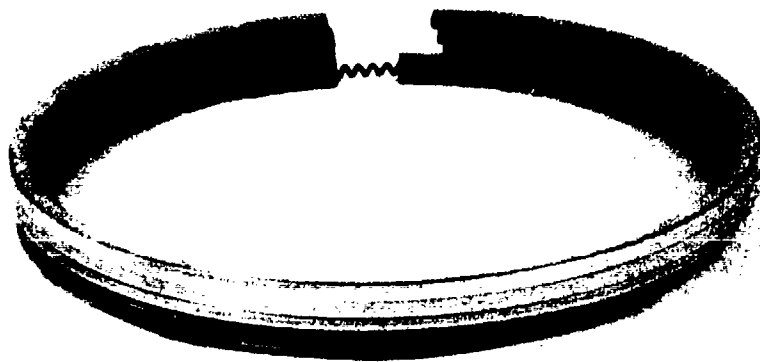
* Piston 6 had the lowest WTD rating.

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF RINGS



Piston No. 1



Piston No. 2



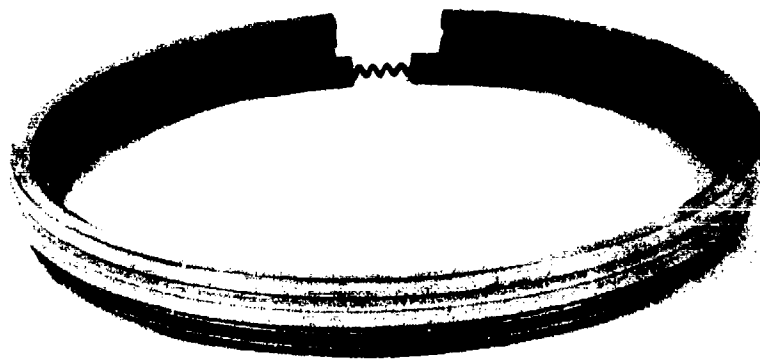
Piston No. 3

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF RINGS



Piston No. 4



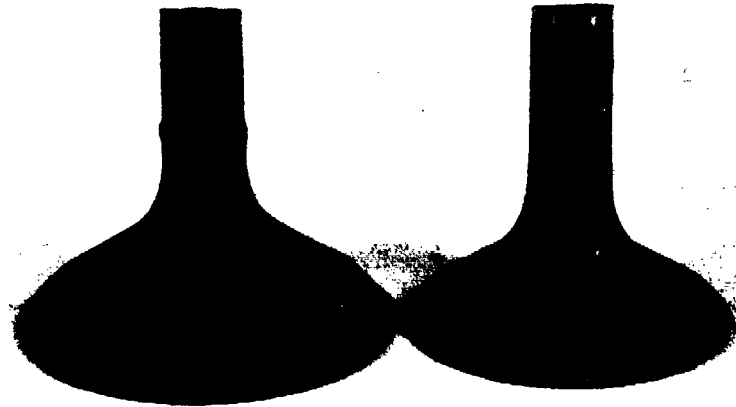
Piston No. 5



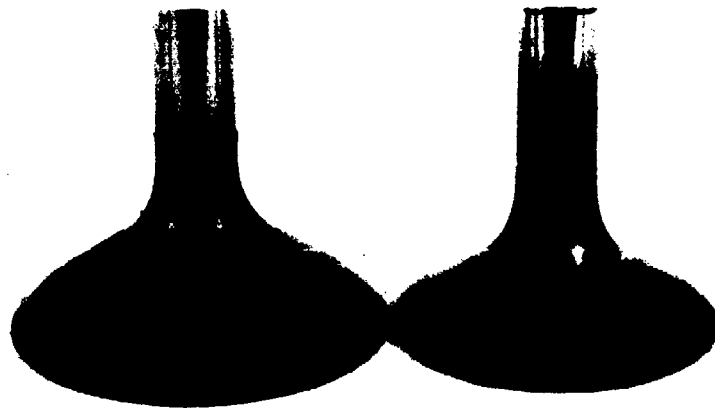
Piston No. 6

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

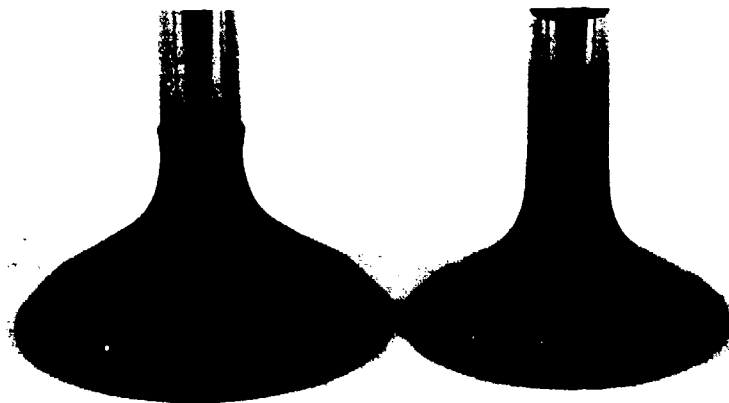
AFTER TEST CONDITION OF INTAKE AND EXHAUST VALVES



No. 1



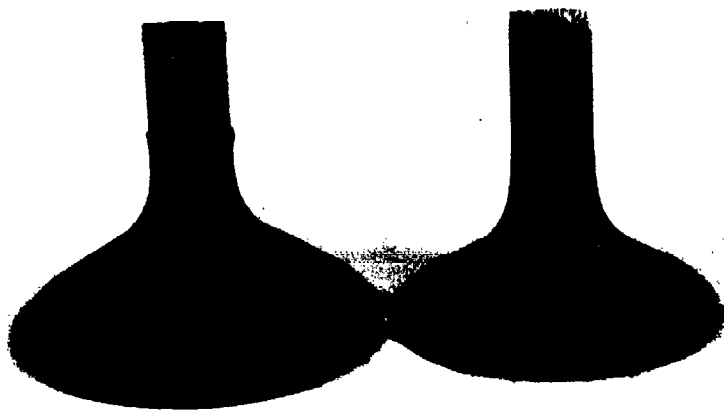
No. 2



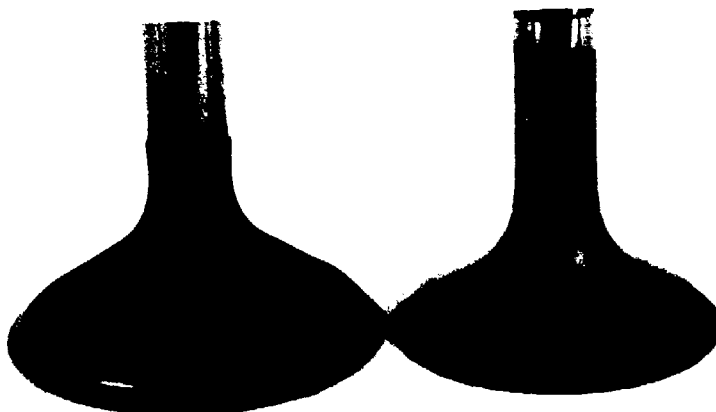
No. 3

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

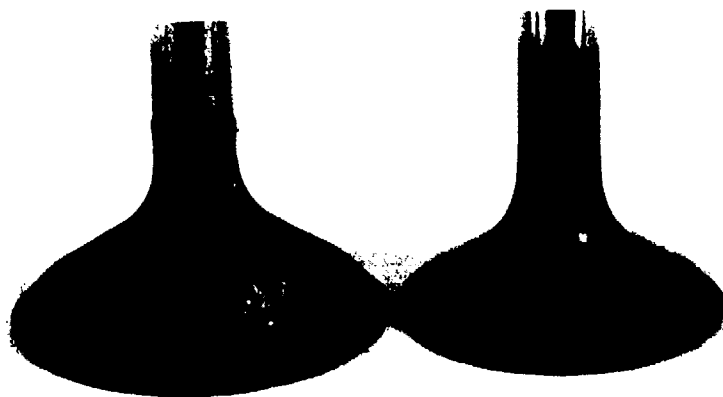
AFTER TEST CONDITION OF INTAKE AND EXHAUST VALVES



No. 4



No. 5



No. 6

L-31

LDT-465-1C
TEST 5
Lubricant: AL-8924-L

AFTER TEST CONDITION OF CYLINDER HEADS

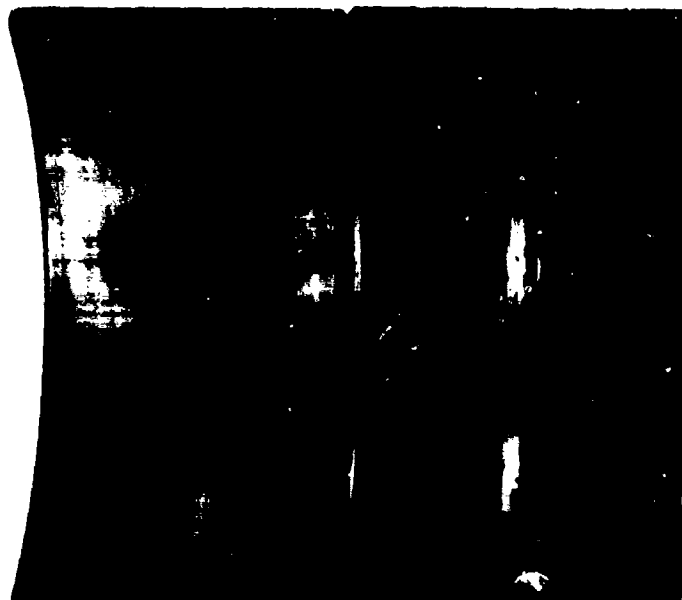


Cylinders 3, 2, 1



Cylinders 6, 5, 4

LDT-465-1C
TEST 5
Lubricant: AL-8924-L



No. 4



No. 5

AFTER TEST CONDITION OF NOS. 4 and 5 CONNECTING ROD BEARINGS

APPENDIX M

**ENGINE-LUBRICANT COMPATIBILITY TEST #6
210-HOUR WHEELED-VEHICLE CYCLE
USING LDT-465-1C DIESEL ENGINE**

**ENGINE-LUBRICANT COMPATIBILITY TEST
210-HOUR WHEELED-VEHICLE CYCLE
USING LDT-465-1C DIESEL ENGINE**

**Test Lubricant: AL-9249-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 6
Date Completed: 10 April 1980**

Conducted for

**U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia**

by

**U.S. Army Fuels & Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284**

LDT-465-1C
Test 6
ENGINE REBUILD MEASUREMENTS

	Inches			
<u>Cylinder Liners (Installed)</u>	<u>Min</u>	<u>Max</u>	<u>Avg</u>	<u>Specified Limits</u>
Inside Diameter	4.5630	4.5641	4.5637	4.5630-4.5645
Out of Round	0.0001	0.0010	0.0005	0.0015 Max.
Taper	0.0000	0.0008	0.0003	0.0015 Max.
Piston Skirt Diameter (@ bottom)	4.5550	4.5554	4.5552	4.5530-4.5580
<u>No. 1 Ring</u>				
End Gap	0.021	0.026	0.024	0.022-0.035
<u>No. 2 Ring</u>				
End Gap	0.020	0.026	0.023	0.022-0.035
<u>No. 3 Ring</u>				
End Gap	0.021	0.024	0.022	0.010-0.028
Side Clearance	0.02	0.03	0.03	0.0025-0.0045
<u>No. 4 Ring</u>				
End Gap	0.020	0.021	0.021	0.010-0.028
Side Clearance	0.01	0.02	0.02	0.0010-0.0035

LDT-465-1C

210-HOUR WHEELED VEHICLE CYCLE ENDURANCE TEST
TEST 6

OPERATING CONDITIONS SUMMARY

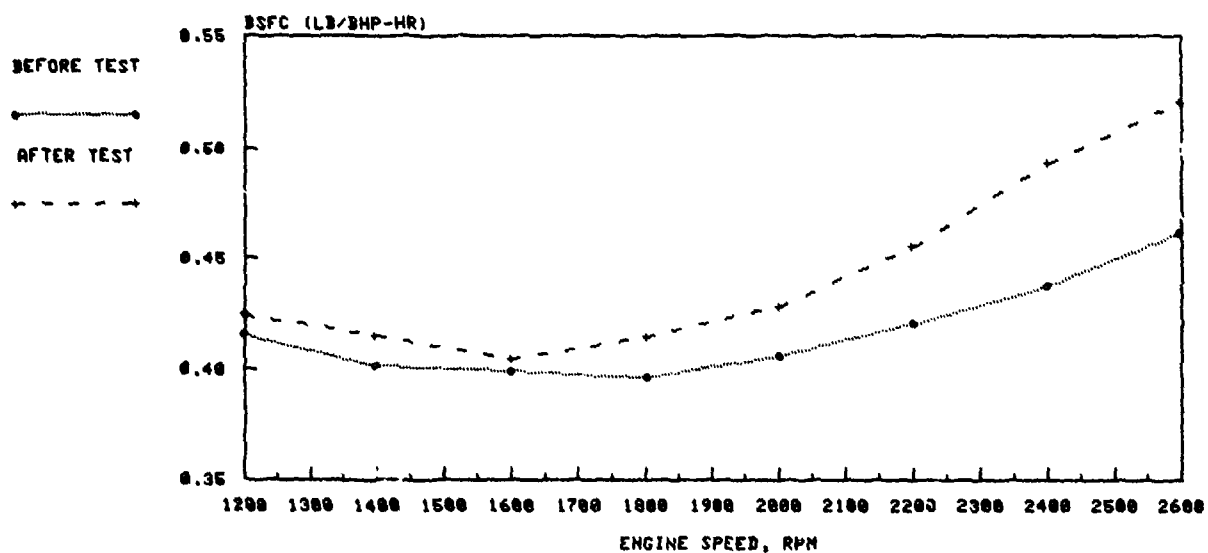
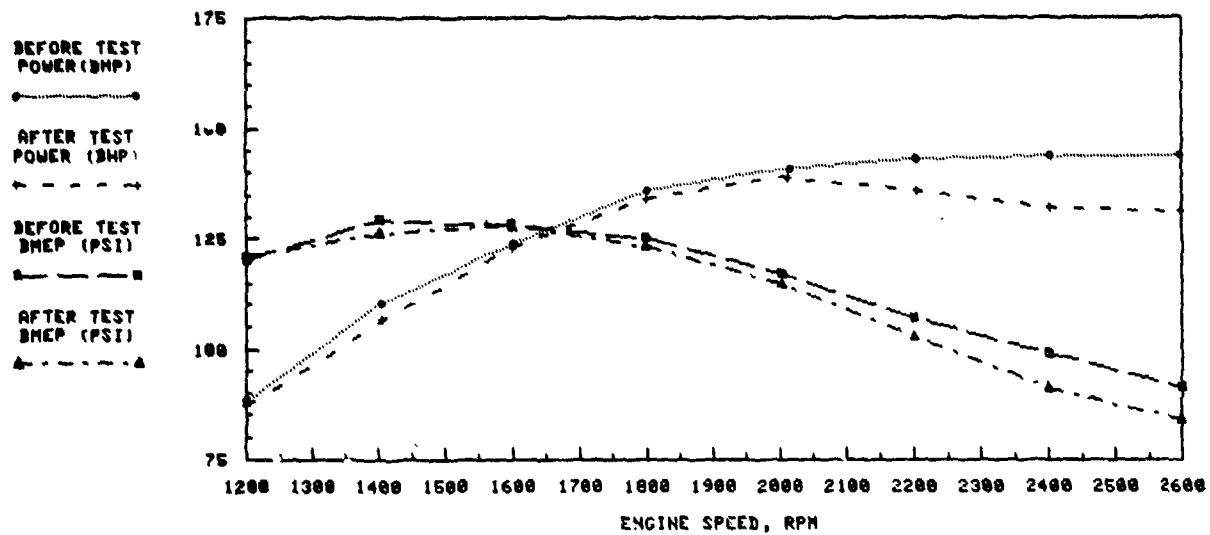
Fuel: Cat 1-H Lubricant: AL-9249-L

	<u>Power Mode</u>			<u>Idle Mode</u>
	<u>Min.</u>	<u>Max.</u>	<u>Avg.</u>	<u>AVG.</u>
Engine Speed, RPM	2599	2610	2603	802
Torque, ft-lb (N-m)	253 (343)	295 (400)	279 (378)	13 (18)
Observed Power, Bhp (kW)	126 (94)	146 (109)	138 (103)	2.0 (15)
Fuel Consumption, lb/hr (kg/hr)	66.1 (30.0)	68.9 (31.3)	66.7 (30.3)	5.2 (2.4)
BSFC, lb/Bhp-hr (g/kW-hr)	0.456 (289)	0.516 (327)	0.484 (307)	2.6 (1650)
<u>Temperatures, °F (°C)</u>				
Exhaust Manifold	1057 (569)	1160 (627)	1087 (586)	251 (122)
Water Jacket Inlet	167 (75)	171 (77)	169 (76)	93 (34)
Water Jacket Outlet	179 (82)	182 (83)	181 (83)	99 (37)
Oil Sump	231 (111)	237 (114)	233 (122)	121 (49)
Fuel In	83 (29)	95 (35)	90 (32)	79 (26)
Inlet Air	84 (29)	97 (36)	89 (32)	79 (26)
Intake Manifold	236 (113)	267 (131)	251 (122)	81 (27)
<u>Pressures</u>				
Intake Vacuum, in. H ₂ O (Pa)	2.8 (700)	3.0 (750)	2.9 (720)	0.0 (0.0)
Exhaust Common, in. Hg (kPa)	0.9 (3.1)	1.1 (3.7)	0.9 (3.1)	0.0 (0.0)
Intake Manifold, psi (kPa)	10.5 (72.3)	12.3 (84.7)	11.0 (75.8)	0.0 (0.0)
Exhaust Manifold, psi (kPa)	12.0 (82.7)	13.5 (93.0)	12.6 (86.8)	0.0 (0.0)
Fuel Transfer Pump, psi (kPa)	72 (496)	73 (503)	73 (503)	38 (262)
Oil Gallery, psi (kPa)	64 (441)	66 (455)	65 (448)	74 (510)
Blowby, in. H ₂ O (Pa)	1.3 (320)	1.5 (370)	1.4 (350)	0.2 (50)
<u>Ambient Conditions</u>				
Wet Bulb Temperature, °F (°C)			68 (20)	
Dry Bulb Temperature, °F (°C)			78 (26)	
Barometric Pressure, in. Hg (kPa)			29.07	

Unscheduled Shutdowns

35 hrs. - broken oil pump idler gear shaft
 47 hrs. - broken oil pump idler gear shaft

LDT-465 210 HOUR WHEELED VEHICLE CYCLE BEFORE AND AFTER TEST 6 PERFORMANCE DATA



LDT-465-1C
TEST 6
LUBRICANT ANALYSIS

Lubricant: AL-9249-L

	ASTM Test Method	Test Time, Hours			
		0	70	140	210
Apparent Viscosity at -29°C (-20°F), cP	D 2602	22800	39600	>78900*	>78900*
Apparent Viscosity at -18°C (0°F), cP	D 2602	3900	6400	11000	14900
Kinematic Viscosity at 40°C (104°F), cSt	D 445	96.7	116.9	150.1	179.9
Kinematic Viscosity at 100°C (212°F), cSt	D 445	13.9	15.4	18.0	20.3
Viscosity Index	D 2270	146	139	134	131
Total Acid Number, mg KOH/g	D 664	3.3	4.0	5.5	5.8
Total Base Number, mg KOH/g	D 664	6.5	3.7	2.6	2.6
Pentane B Insolubles, wt %	D 893	-	0.6	1.9	3.2
Toluene B Insolubles, wt %	D 893	-	0.5	1.5	2.4
Flash Point, °C (°F)	D 92	209 (408)	220 (428)	220 (428)	224 (435)
Density at 16°C (60°F), gm/ml	D 287	0.88	0.89	0.90	0.91
Carbon Residue, wt %	D 524	1.2	2.0	3.0	3.9
Sulfated Ash, wt %	D 874	1.0	1.2	1.6	1.9

*The lubricant viscosities at these test times exceeded the currently available Cold Cranking Simulator viscosity standards.

LDT-465-1C
TEST 6
Lubricant: AL-9249-L
TOTAL OIL CONSUMPTION AND WEAR METALS

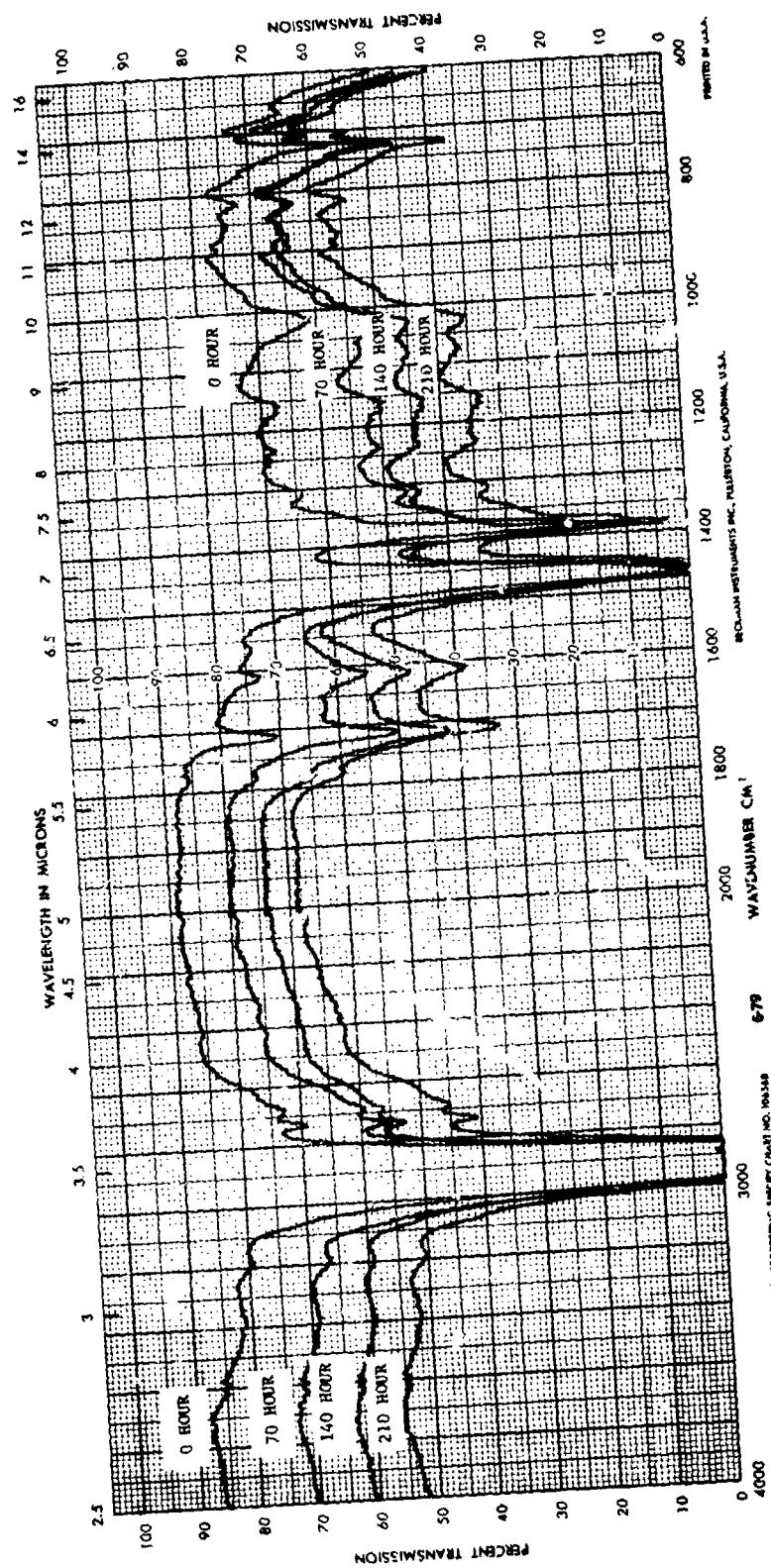
<u>Test Time, Hours</u>	<u>Total Oil Consumed, lb (kg)</u>	<u>Wear Metals⁺, ppm</u> <u>Fe (Iron)</u>
14	5.0 (2.3)	33
28	9.8 (4.4)	28
42	12.1* (5.5)	43
56	12.1 (5.5)	50
70	14.5 (6.6)	61
84	18.4 (8.3)	64
98	26.5 (12.0)	72
112	30.8 (14.0)	83
126	36.3 (16.5)	107
140	43.5 (19.7)	120
154	50.3 (22.8)	117
168	56.5 (25.6)	136
182	64.8 (29.4)	140
196	73.2 (33.2)	156
210	80.4 (36.5)	157

Average Oil Consumption Rate: 0.38 lb/hr (0.17 kg/hr)

⁺No other wear metals detected

*When the oil pan was removed to repair the oil pump idler gear shaft at 35 and 47 hours, the oil sump was refilled to "Full", taking 8.5 and 10.5 lb, respectively.

LDT-465-1C
 TEST 6
 Lubricant: AL-9249-L



LDT-465-1C

TEST 6

Lubricant: AL-9249-L

WEAR MEASUREMENTS

CYLINDER LINER BORE DIAMETER, INCHES

	<u>Before Test</u>			<u>After Test</u>			<u>Change</u>		
	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>
1 T-AT	4.5640	4.5641	4.5638	4.5648	4.5646	4.5643	+0.0008	+0.0005	+0.0005
F-B	4.5630	4.5636	4.5636	4.5635	4.5637	4.5637	+0.0005	+0.0001	+0.0001
2 T-AT	4.5640	4.5641	4.5644	4.5651	4.5650	4.5652	+0.0011	+0.0009	+0.0008
F-B	4.5637	4.5636	4.5638	4.5638	4.5634	4.5635	+0.0001	-0.0002	-0.0003
3 T-AT	4.5633	4.5638	4.5638	4.5643	4.5644	4.5646	+0.0010	+0.0006	+0.0008
F-B	4.5632	4.5631	4.5632	4.5638	4.5633	4.5633	+0.0006	+0.0003	+0.0001
4 T-AT	4.5637	4.5639	4.5643	4.5647	4.5644	4.5646	+0.0010	+0.0005	+0.0003
F-B	4.5641	4.5641	4.5639	4.5648	4.5643	4.5643	+0.0007	+0.0002	+0.0004
5 T-AT	4.5639	4.5640	4.5637	4.5647	4.5645	4.5642	+0.0008	+0.0005	+0.0005
F-B	4.5631	4.5630	4.5635	4.5636	4.5634	4.5638	+0.0005	+0.0004	+0.0003
6 T-AT	4.5636	4.5635	4.5636	4.5644	4.5642	4.5641	+0.0008	+0.0007	+0.0005
F-B	4.5641	4.5636	4.5633	4.5644	4.5639	4.5636	+0.0003	+0.0003	+0.0003

Average Change, in.: +0.0005

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

WEAR MEASUREMENTS

PISTON RING END GAP, INCHES

<u>Piston No.</u>	<u>Ring No.</u>	<u>Before Test End Gap</u>	<u>After Test End Gap</u>	<u>Change</u>
1	1	0.025	0.027	+0.002
	2	0.025	0.028	+0.003
	3	0.022	0.024	+0.002
	4	0.021	0.024	+0.003
2	1	0.023	0.025	+0.002
	2	0.022	0.023	+0.001
	3	0.024	0.025	+0.001
	4	0.020	0.022	+0.002
3	1	0.020	0.022	+0.002
	2	0.021	0.022	+0.001
	3	0.023	0.025	+0.002
	4	0.022	0.023	+0.001
4	1	0.026	0.027	+0.001
	2	0.025	0.027	+0.002
	3	0.021	0.022	+0.001
	4	0.021	0.024	+0.003
5	1	0.021	0.022	+0.001
	2	0.020	0.021	+0.001
	3	0.021	0.021	0.000
	4	0.020	0.024	+0.004
6	1	0.026	0.027	+0.001
	2	0.026	0.027	+0.001
	3	0.022	0.024	+0.002
	4	0.021	0.025	+0.004

Average Change , in.: +0.002

LDT-465-1C
TEST 6

Lubricant: AL-9249-L

POST TEST ENGINE CONDITION AND DEPOSITS

A. Cylinder Rating	CYLINDER NUMBER											
	1		2		3		4		5		6	
	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq
<u>Deposits</u>												
Cylinder Head	10% ⁺ AHC 90% ½AHC	0	10% ⁺ AHC 90% ½AHC	0	10% ⁺ AHC 90% ½AHC	0	5%AHC 95% ½AHC	0	5%AHC 95% ½AHC	0	5%AHC 95% ½AHC	0
Cylinders ART ^{**}	35%AHC	30%-3 25%-5 10%-7	60%AHC	20%-2 20%-4	30%AHC	70%-3	30%AHC	40%-2 20%-4 10%-6	40%AHC	55%-2	40%AHC	20%-2 30%-4 10%-8
RTA	0	73%-4 5%-5 20%-6 2%-8	0	95%-4 5%-8	0	100%-4	0	95%-4 5%-8	0	100%-4	0	95%-4 5%-8
BRT	0	100%-7	0	100%-7	0	100%-7	0	100%-7	0	100%-7	0	100%-7
<u>Surface Condition</u> ⁺⁺												
Cylinder RTA	5%-G 95%-LS		10%-LSC 90%-LS		20%-G 80%-LS		5%-G 5%-SC 90%-LS		5%-LSC 95%-LS		50%-LSC 50%-LS	

<u>B. Piston Ratings</u>												
Ring Face Condition	----- All Rings Normal, All Oil Slots Open 100% -----											
Ring Deposits	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq
Top Ring												
1	0	0	0	0	0	0	0	5%-6	0	5%-6	0	0
2	0	10%-3 5%-5	0	15%-3	0	10%-3	5% ½AHC	10%-3	0	40%-4	5% ½AHC	10%-3 5%-4
3	0	100%-7	0	95%-6 5%-8	0	95%-7 5%-8	0	100%-7	0	70%-6 30%-7	0	15%- 85%-7

*HC = Hard Carbon; the number-letter prefix indicates carbon depth; with ½A = least, through the alphabet, to J = most.

**ART = Above Ring Travel, RTA = Ring Travel Area, BRT = Below Ring Travel.

+The higher the number, the darker the lacquer. (0 = lightest, 9 = darkest).

++V = very, L = light, H = heavy, G = glazing, P = pitting, W = wiping, F = flaking, S = scratched, SC = scuffed, T = thrust side, AT = antithrust side, RS = ring supporting.

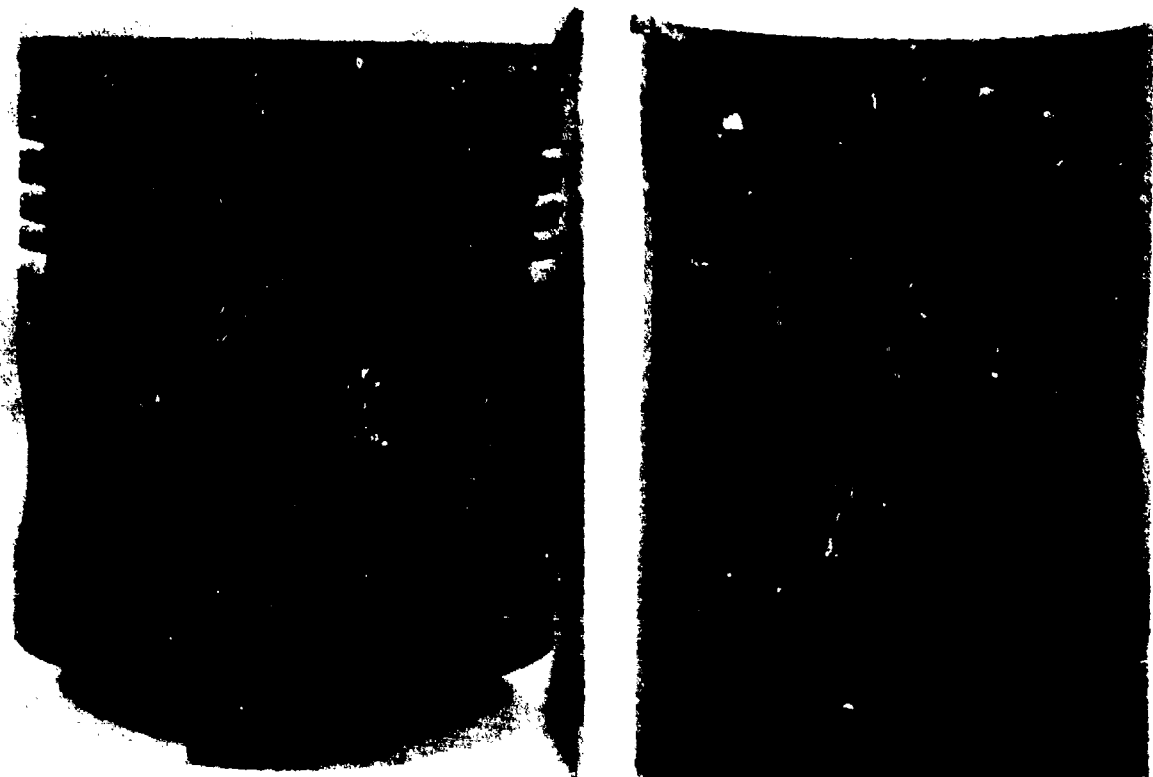
Piston Ratings		1		2		3		4		5		6					
Ring Deposit; cor		Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq				
ID	Ring																
	1	100%RS	0	5%RS 95%AHC	0	75% 1/2AHC	25%-2	30%AHC	50%-3	100% 1/2AHC	0	100%AHC	0				
	2	80%AHC	20%-5	100% 1/2AHC	0	100%AHC	0	100%AHC	0	45%RS 55% 1/2AHC	0	100% 1/2AHC	0				
	3	100% 1/2AHC	0	100% 1/2AHC	0	100% 1/2AHC	0	100% 1/2AHC	0	100% 1/2AHC	0	100% 1/2AHC	0				
Bottom	Ring																
	1	0	15%-4	0	0	0	0	0	0	0	0	0	0				
	2	0	15%-2	0	10%-3	0	0	0	50%-2	0	10%-2	0	15%-3				
	3	0	40%-3 60%-7	0	25%-4	0	10%-7	0	50%-2 50%-7	0	15%-6	0	10%-4 10%-7				
<u>Piston Surface Condition</u>																	
Top Ring Land		-----						Normal		-----							
Skirt		-----						Normal		-----							
Piston Pin		-----						Normal		-----							
CRC Diesel Engine																	
Piston Rating																	
(WTD)	266			300			282			314			263			220	
C. Valve Ratings		Int	Exh	Int	Exh	Int	Exh	Int	Exh	Int	Exh	Int	Exh				
Freeness in Guide		F	*	F	F	F	F	F	*	F	F	F	*				
Head		-----						Normal		-----							
Face		-----						Normal		-----							
Seat		-----						Normal		-----							
Stem		-----						Normal		-----							
Tip		-----						Normal		-----							
Tulip Demerit Rating		2.0	0.5	1.5	0.5	1.5	0.5	2.0	1.0	2.0	0.5	2.0	0.5				
<u>D. Other Ratings</u>																	
<u>Tappets, Cams, Rocker Arms</u>																	
Tappet Deposit		-----						Clean		-----							
<u>Rocker Arm</u>																	
Tip		-----						Normal		-----							
Bushing		-----						Normal		-----							
Shaft		-----						Normal		-----							
<u>Bearing Surface Condition</u>																	
Main Bearing		N			N			S			S			No. 5, 6, 7, Not Rated			
Main Journal		N			N			N			N			"			
Rod Bearing		-----						Normal		-----							
Rod Journal		-----						Normal		-----							
Piston Pin		-----						Normal		-----							
Pin Bushing		-----						Normal		-----							

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



1 - Thrust

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



1 - Anti-Thrust

M-15

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



2 - Thrust

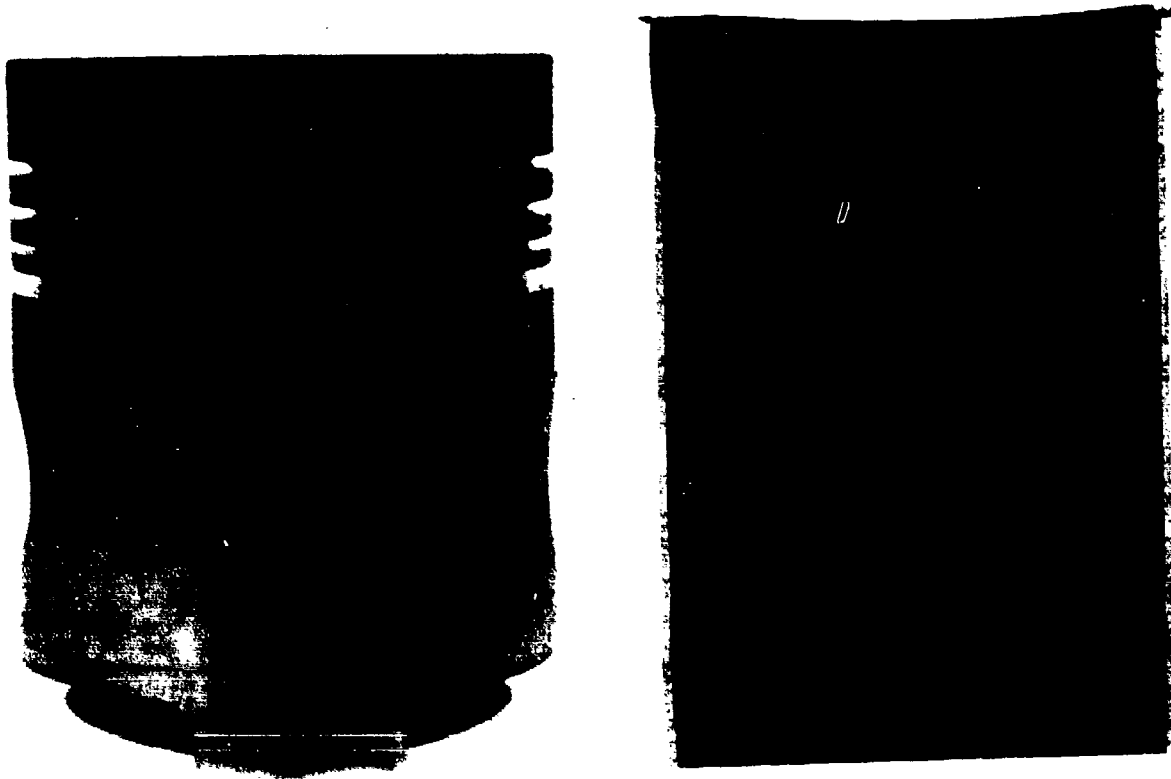
M-16

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



2 - Anti-Thrust

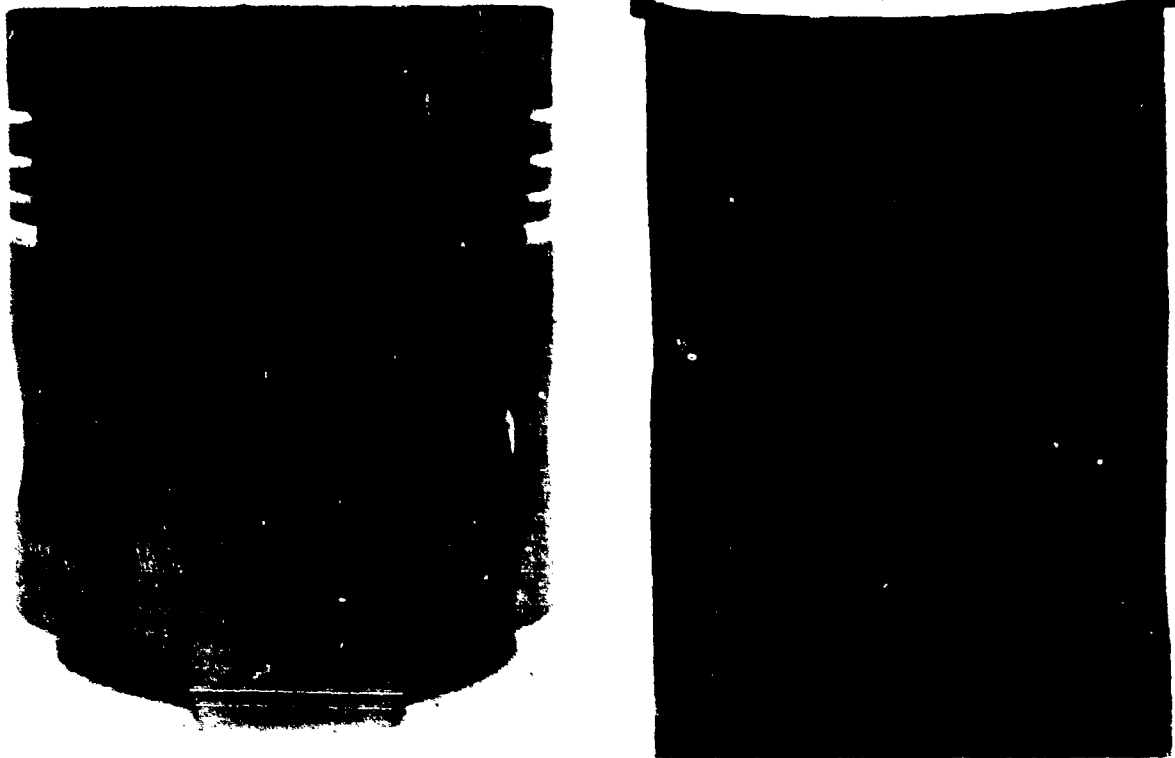
M-17

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



3 - Thrust

M-18

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



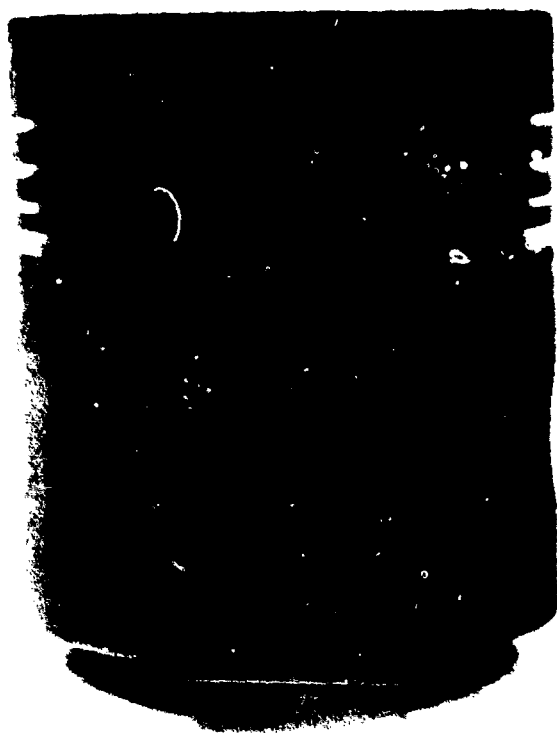
3 - Anti-Thrust

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



4 - Thrust*

*Piston No. 4 had the highest Weighted Total Deposits (WTD) rating.

M-20

LDT-465-1C

TEST 6

Lubricant: AL-0240-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



4 - Anti-Thrust*

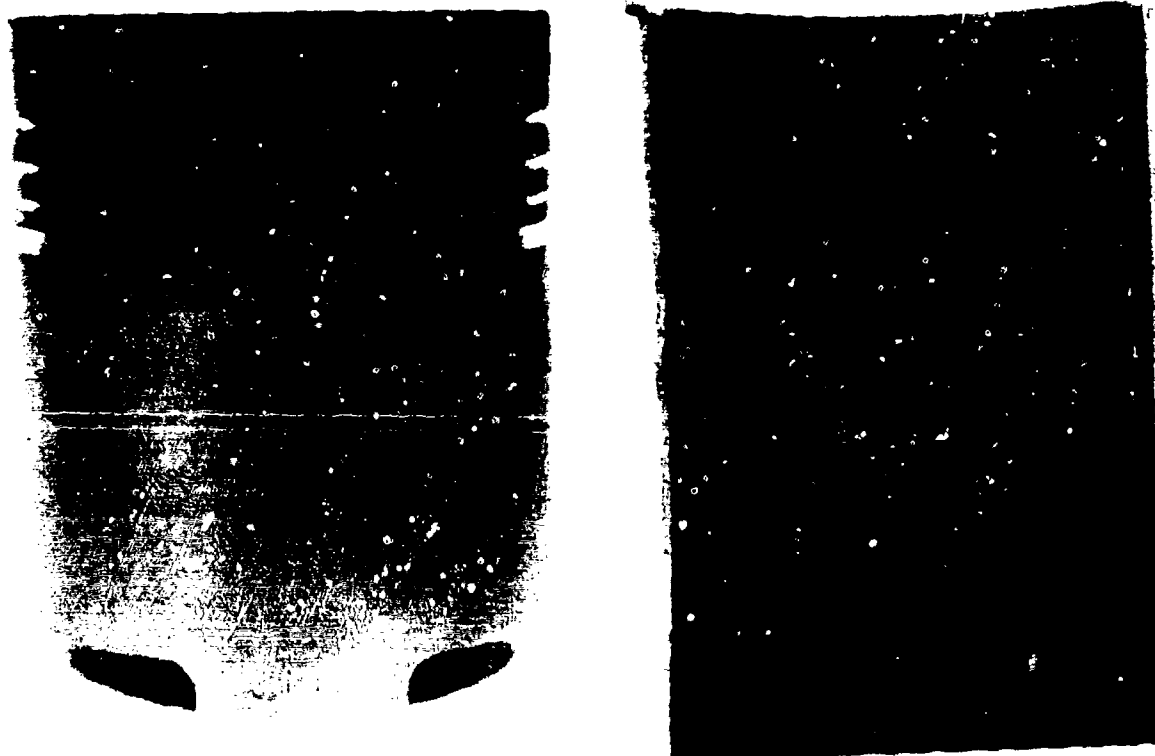
*Piston No. 4 had the highest Weighted Total Deposits (WTD) rating.

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



5 - Thrust

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



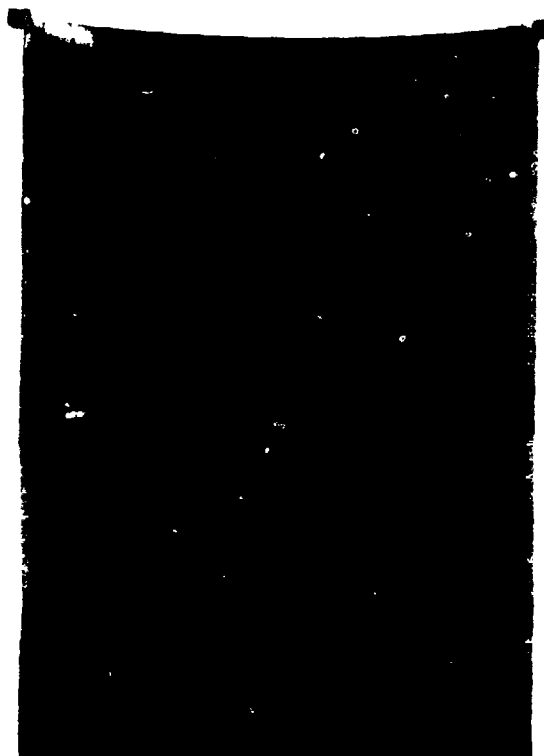
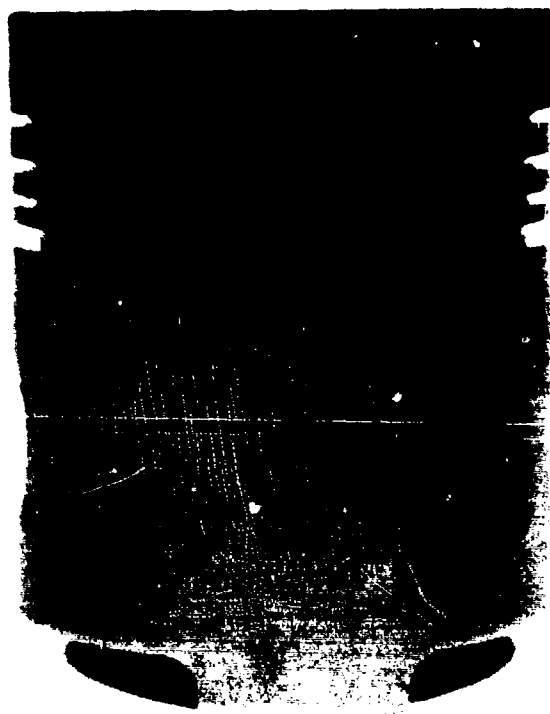
5 - Anti-Thrust

LDT-465-1C

TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



6 - Thrust*

*Piston No. 6 had the lowest Weighted Total Deposits (WTD) rating.

LDT-465-1C
TEST 6
Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON AND CYLINDER LINER



6 - Anti-Thrust*

*Piston No. 6 had the lowest Weighted Total Deposits (WTD) rating.

LDT-465-1C
TEST 6

Lubricant: AL-9249-L

AFTER TEST CONDITION OF PISTON RINGS



Piston No. 1 (largest increase in end gap)



Piston No. 2 (least increase in end gap)



Piston No. 3 (least increase in end gap)

LDT-465-1C
TEST 6

Lubricant: AL-9249-L
AFTER TEST CONDITION OF PISTON RINGS



Piston No. 4



Piston No. 5



Piston No. 6

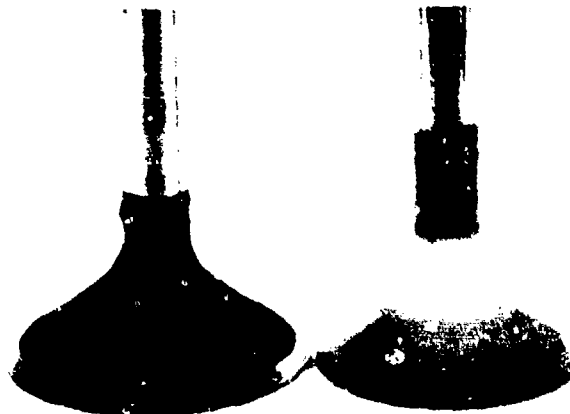
LDT-465-1C
TEST 6

Lubricant: AL-9249-L

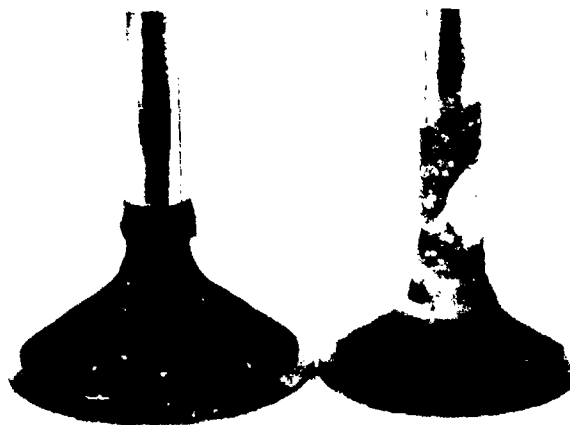
AFTER TEST CONDITION OF INTAKE AND EXHAUST VALVES



Cylinder No. 1



Cylinder No. 2

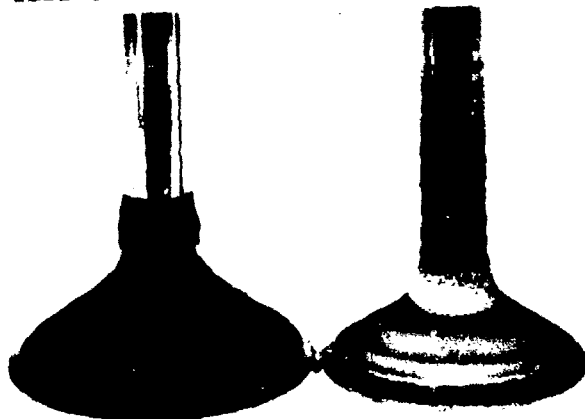


Cylinder No. 3

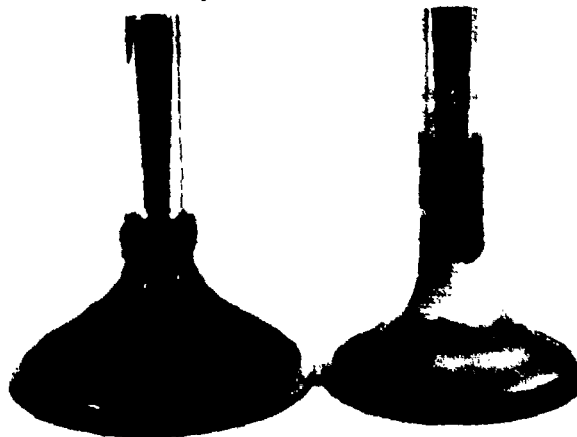
LDT-465-1C
TEST 6

Lubricant: AL-9249-L

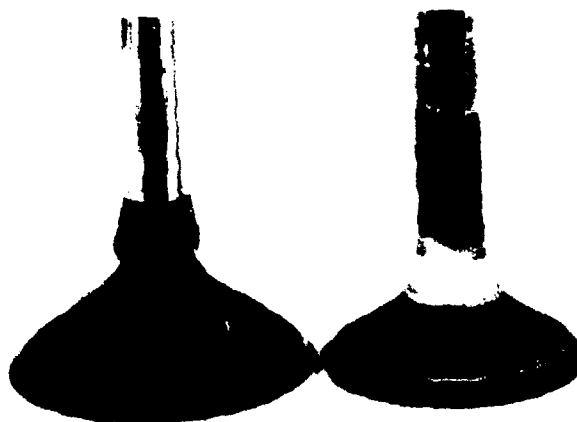
AFTER TEST CONDITION OF INTAKE AND EXHAUST VALVES



Cylinder No. 4



Cylinder No. 5



Cylinder No. 6

DISTRIBUTION LIST

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DALO-AU 1
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DRCMM-SP (LTC O'CONNER) 1
DRCQA-E (MR SMART) 1
DRCDE-DG (MR MCGOWAN) 1
DRCIS-S (MR SPRAGUE) 1
DRCIS-C (LTC CROW) 1
5001 EISENHOWER AVE
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DRSTA-RG (MR HAMPARIAN) 1
DRSTA-NS (DR PETRICK) 1
DRSTA-J 1
DRSTA-G (COL MILLS) 1
DRSTA-M 1
DRSTA-GBP (MR MCCARTNEY) 1
WARREN MI 48090

DIRECTOR
US ARMY MATERIAL SYSTEMS
ANALYSIS AGENCY
ATTN DRXSY-CM 1
DRXSY-S 1
DRXSY-L 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY APPLIED TECH LAB
ATTN DAVDL-ATL-DD 1
DAVDL-ATL-ATP (MR MORROW) 1
DAVDL-ATL-ASV 1
FORT EUSTIS VA 23604
HQ, 172D INFANTRY BRIGADE (ALASKA)
ATTN AFZT-DI-L 1
AFZT-DI-M 1
DIRECTORATE OF INDUSTRIAL
OPERATIONS
FT RICHARDSON AK 99505

CDR
US ARMY GENERAL MATERIAL &
PETROLEUM ACTIVITY
ATTN STSGP-FT (MS GEORGE) 1
STSGP-PE 1
STSGP (COL HILL) 1
NEW CUMBERLAND ARMY DEPOT
NEW CUMBERLAND PA 17070

CDR
US ARMY ARRCOM, LOG ENGR DIR
ATTN DRSAR-LEM (MR MENKE) 1
ROCK ISLAND ARSENAL IL 61299

CDR
US ARMY COLD REGION TEST CENTER
ATTN STECR-TA (MR HASLEM) 1
APO SEATTLE 98733

CDR
US ARMY RES & STDZN GROUP
(EUROPE)
ATTN DRXSN-E-RA 1
BOX 65
FPO NEW YORK 09510

HQ, US ARMY AVIATION R&D CMD
ATTN DRDAV-D (MR CRAWFORD) 1
DRDAV-N (MR BORGMAN) 1
DRDAV-E (MR LONG) 1
P O BOX 209
ST LOUIS MO 63166

CDR
US ARMY FORCES COMMAND
ATTN AFLG-REG (MR HAMMERSTROM) 1
AFLG-POP (MR COOK) 1
FORT MCPHERSON GA 30330

CDR
US ARMY ABERDEEN PROVING GROUND
ATTN STEAP-MT 1
STEAP-MT-U (MR DEEVER) 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY YUMA PROVING GROUND
ATTN STEYP-MT (MR DOEBLER) 1
YUMA AR 85364

MICHIGAN ARMY MISSILE PLANT
OFC OF PROJ MGR, XM-1 TANK SYS
ATTN DRCPM-GCM-S 1
WARREN MI 48090

MICHIGAN ARMY MISSILE PLANT
PROG MGR, FIGHTING VEHICLE SYS
ATTN DRCPM-FVS-SE 1
WARREN MI 48090

PROJ MGR, M60 TANK DEVELOPMENT
ATTN DRCPM-M60-E (MR WESALA) 1
WARREN MI 48090

PROG MGR, M113/M113A1 FAMILY
OF VEHICLES
ATTN DRCPM-M113 1
WARREN MI 48090

PROJ MGR, MOBILE ELECTRIC POWER
ATTN DRCPM-MEP-TM 1
7500 BACKLICK ROAD
SPRINGFIELD VA 22150

OFC OF PROJ MGR, IMPROVED TOW
VEHICLE
US ARMY TANK-AUTOMOTIVE R&D CMD
ATTN DRCPM-ITV-T 1
WARREN MI 48090

CDR
US ARMY EUROPE & SEVENTH ARMY
ATTN AEAGC-FMD 1
APO NY 09403

PROJ MGR, PATRIOT PROJ OFC
ATTN DRCPM-MD-T-G 1
US ARMY DARCOM
REDSTONE ARSENAL AL 35809

CDR
THEATER ARMY MATERIAL MGMT
CENTER (200TH)
DIRECTORATE FOR PETROL MGMT
ATTN AEAGD-MM-PT-Q (MR PINZOLA) 1
ZWEIBRUCKEN
APO NY 09052

CDR
US ARMY RESEARCH OFC
ATTN DRXRO-EG 1
DRXRO-CB (DR GHIRARDELLI) 1
DRXRO-TT (DR SCHMIEORSHOFF) 1
P O BOX 12211
RSCH TRIANGLE PARK NC 27709

DIR
US ARMY R&T LAB
ADVANCED SYSTEMS RSCH OFC
ATTN MR D WILSTED 1
AMES RSCH CTR
MOFFITT FIELD CA 94035

CDR TOBYHANNA ARMY DEPOT ATTN SDSTO-TP-S TOBYHANNA PA 18466	1	HQ, US ARMY ARMAMENT R&D CMD ATTN DRDAR-SCM-OO (MR MUFFLEY) DRDAR-TST-S DOVER NJ 07801	1 1
DIR US ARMY MATERIALS & MECHANICS RSCH CTR ATTN DRXMR-E DRXMR-T DRXMR-R WATERTOWN MA 02172	1 1 1	HQ, US ARMY TROOP SUPPORT & AVIATION MATERIAL READINESS COMMAND ATTN DRSTS-MEG (2) DRCPO-PDE (LTC FOSTER) 4300 GOODFELLOW BLVD ST LOUIS MO 63120	1 1
CDR US ARMY DEPOT SYSTEMS CMD ATTN DRSDS CHAMBERSBURG PA 17201	1	DEPARTMENT OF THE ARMY CONSTRUCTION ENG RSCH LAB ATTN CERL-EM CERL-ZT CERL-EH P O BOX 4005 CHAMPAIGN IL 61820	1 1 1
CDR US ARMY WATERVLIET ARSENAL ATTN SARWY-RDD WATERVLIET NY 12189	1	HQ US ARMY TRAINING & DOCTRINE CMD ATTN ATCD-SL (MR RAFFERTY) ATCD-TA ATCD-D FORT MONROE VA 23651	1 1 1
CDR US ARMY LEA ATTN DALO-LEP NEW CUMBERLAND ARMY DEPOT NEW CUMBERLAND PA 17070	1	DIRECTOR US ARMY RSCH & TECH LAB (AVRADCOM) PROPULSION LABORATORY ATTN DAVDL-PL-D (MR ACURIO) 21000 BROOKPARK ROAD CLEVELAND OH 44135	1
CDR US ARMY GENERAL MATERIAL & PETROLEUM ACTIVITY ATTN STSGP-PW (MR PRICE) SHARPE ARMY DEPOT LATHROP CA 95330	1	CDR US ARMY NATICK RES & DEV CMD ATTN DRDNA-YEP (DR KAPLAN) NATICK MA 01760	1
CDR US ARMY FOREIGN SCIENCE & TECH CENTER ATTN DRXST-MT1 FEDERAL BLDG CHARLOTTESVILLE VA 22901	1	CDR US ARMY TRANSPORTATION SCHOOL ATTN ATSP-CD-MS FORT EUSTIS VA 23604	1
CDR DARCOM MATERIAL READINESS SUPPORT ACTIVITY (MRSA) ATTN DRXMD-MD LEXINGTON KY 40511	1	CDR US ARMY QUARTERMASTER SCHOOL ATTN ATSM-CTD-MS ATSM-TNG-PT (COL VOLPE) FORT LEE VA 23801	1 1
HQ, US ARMY T&E COMMAND ATTN DRSTE-TO-O ABERDEEN PROVING GROUND, MD 21005	1	HQ, US ARMY ARMOR SCHOOL ATTN ATSB-TD FORT KNOX KY 40121	1

CDR
US ARMY LOGISTICS CTR
ATTN ATCL-MS (MR A MARSHALL) 1
FORT LEE VA 23801

CDR
US ARMY FIELD ARTILLERY SCHOOL
ATTN ATSF-CD 1
FORT SILL OK 73503

CDR
US ARMY ORDNANCE CTR & SCHOOL
ATTN ATSL-CTD-MS 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY ENGINEER SCHOOL
ATTN ATSE-CDM 1
FORT BELVOIR VA 22060

CDR
US ARMY INFANTRY SCHOOL
ATTN ATSH-CD-MS-M 1
FORT BENNING GA 31905

CDR
US ARMY AVIATION CTR & FT RUCKER
ATTN ATZQ-D 1
FORT RUCKER AL 36362

DEPARTMENT OF THE NAVY

CDR
NAVAL AIR PROPULSION CENTER
ATTN PE-71 1
PE-72 (MR D'ORAZIO) 1
P O BOX 7176
TRENTON NJ 06828

CDR
NAVAL SEA SYSTEMS CMD
CODE 6101F (MR R LAYNE) 1
WASHINGTON DC 20362

CDR
DAVID TAYLOR NAVAL SHIP R&D CTR
CODE 2830 (MR G BOSMAJIAN) 1
CODE 2831 1
ANNAPOLIS MD 21402

JOINT OIL ANALYSIS PROGRAM -
TECHNICAL SUPPORT CTR 1
BLDG 780
NAVAL AIR STATION
PENSACOLA FL 32508

DEPARTMENT OF THE NAVY
HQ, US MARINE CORPS
ATTN LPP (MAJ SANBERG) 1
LMM (MAJ GRIGGS) 1
WASHINGTON DC 20380

CDR
NAVAL AIR SYSTEMS CMD
ATTN CODE 52032E (MR WEINBURG) 1
CODE 53645 1
WASHINGTON DC 20361

CDR
NAVAL AIR DEVELOPMENT CTR
ATTN CODE 60612 (MR L STALLINGS) 1
WARMINSTER PA 18974

CDR
NAVAL RESEARCH LABORATORY
ATTN CODE 6170 (MR H RAVNER) 1
CODE 6180 1
CODE 6110 (DR HARVEY) 1
WASHINGTON DC 20375

CDR
NAVAL FACILITIES ENGR CTR
ATTN CODE 1202B (MR R BURRIS) 1
CODE 120B (MR BUSCHELMAN) 1
200 STOVWALL ST
ALEXANDRIA VA 22322

CHIEF OF NAVAL RESEARCH
ATTN CODE 473 (DR R MILLER) 1
ARLINGTON VA 22217

CDR
NAVAL AIR ENGR CENTER
ATTN CODE 92727 1
LAKEHURST NJ 08733

CDR
NAVY FACILITIES ENGRG CMD
CIVIL ENGR SUPPORT OFC
CODE 15312A (ATTN EOC COOK) 1
NAVAL CONSTRUCTION BATTALION CTR
PORT HUENEME CA 93043

CDR, NAVAL MATERIAL COMMAND
ATTN MAT-08E (DR A ROBERTS) 1
CP6, RM 606 MAT-08E (MR ZIEM) 1
WASHINGTON DC 20360

CDR
NAVY PETROLEUM OFC
ATTN CODE 40 1
CAMERON STATION
ALEXANDRIA VA 22314

CDR
MARINE CORPS LOGISTICS SUPPORT
BASE ATLANTIC
ATTN CODE P841 1
ALBANY GA 31704

DEPARTMENT OF THE AIR FORCE

HQ, USAF
ATTN RDPT 1
WASHINGTON DC 20330

HQ AIR FORCE SYSTEMS CMD
ATTN AFSC/DLF (LTC RADLOF) 1
ANDREWS AFB MD 20334

CDR
US AIR FORCE WRIGHT AERONAUTICAL
LAB
ATTN AFWAL/POSF (MR CHURCHILL) 1
AFWAL/POSL (MR JONES) 1
WRIGHT-PATTERSON AFB OH 45433

CDR
USAF SAN ANTONIO AIR LOGISTICS
CTR
ATTN SAALC/SFQ (MR MAKRIS) 1
SAALC/MMPRR (MR ELLIOT) 1
KELLY AIR FORCE BASE, TX 78241

CDR
US AIR FORCE WRIGHT AERONAUTICAL
LAB
ATTN AFWAL/MLSE (MR MORRIS) 1
AFWAL/MLBT 1
WRIGHT-PATTERSON AFB OH 45433

CDR
USAF WARNER ROBINS AIR LOGISTIC
CTR
ATTN WR-ALC/MMIRAB-1 (MR GRAHAM) 1
ROBINS AFB GA 31098

OTHER GOVERNMENT AGENCIES

US DEPARTMENT OF TRANSPORTATION
ATTN AIRCRAFT DESIGN CRITERIA
BRANCH 2

FEDERAL AVIATION ADMIN
2100 2ND ST SW
WASHINGTON DC 20590

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CTR 2

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NORMAN OK 73069

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